NEW

INDUSTRIAL REVOLUTION

DISCOVER HOW THE RISE OF MACHINES CHANGED BRITAIN AND BEYOND

LUDDITES
WHY DID THESE WORKERS FIGHT BACK AGAINST THE FACTORIES?

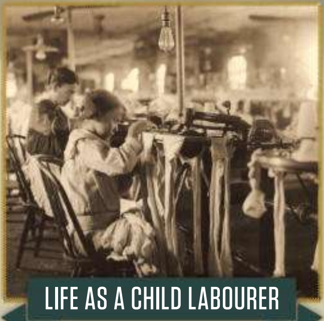
EXPLORE THE CRUCIAL ROLE THAT WOMEN PLAYED IN SCIENCE & INDUSTRY

MEET THE PIONEERS WHOSE RAILWAYS & SHIPS TRANSFORMED TRAVEL & TRADE

LEARN ABOUT THE REMARKABLE CAREER OF BRUNEL, THE ENGINEER WHO CONNECTED A NATION

FROM THE MAKERS OF ALL ABOUT HISTORY

THE AGE OF STEEL & STEAM



LIFE AS A CHILD LABOURER

BUILDING THE FUTURE

A NEW WAY OF WAR

Digital Edition

FUTURE
SECOND EDITION

WELCOME

It is no exaggeration to say that the Industrial Revolution remains the most defining era in British history. In less than a century, a country home to 7.5 million that had for centuries relied on skilled craftspeople and the sweat of farm labourers to sustain it morphed into a land of towering factories and whirring machines, its cities and towns swelling to accommodate a skyrocketing population as workers rushed to find employment in a rapidly changing world.

But why did this sudden explosion in industry begin in Britain in the mid-18th century? Who were the ingenious creators behind the machines that gave rise to cheaper, more efficient manufacturing and travel? And how did the dramatic changes to the way people worked and lived impact British society and eventually the wider world?

Prepare to pick your way through the crash and clamour of the steam age to find the answers to these crucial questions and many more.

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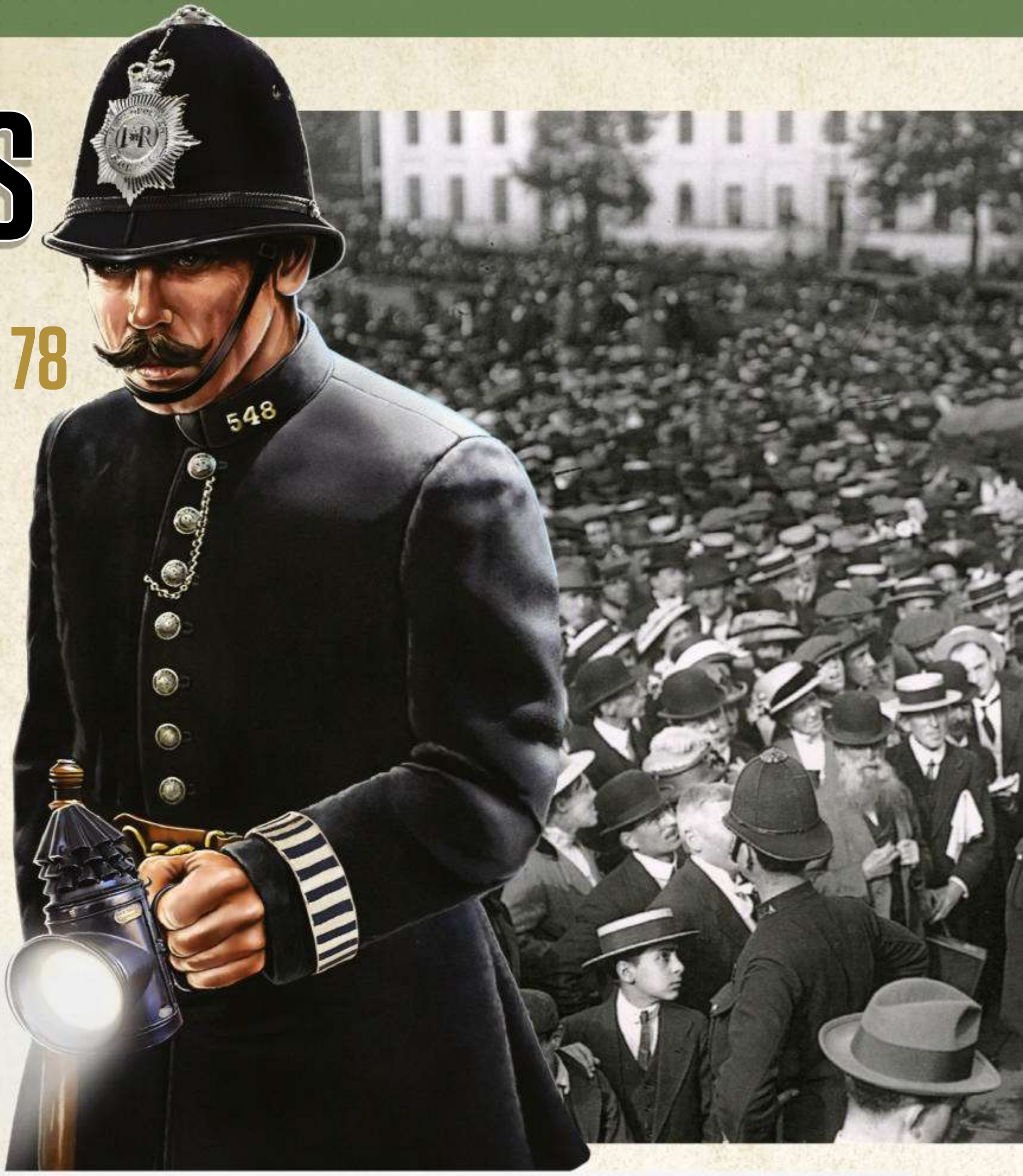

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TIMELINE OF THE REVOLUTION

Bridley's original Bridgewater Canal aqueduct over the River Irwell

THE FIRST TRANSPORT SYSTEM

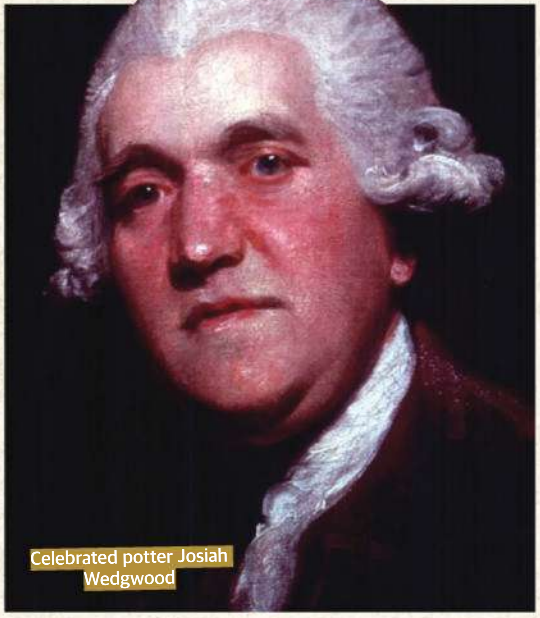
BRITAIN 1761

The transportation of heavy goods was vital for the Industrial Revolution to take hold. Canals – man-made rivers deep enough to take barges laden with cargo over long distances – were seen as the answer. The Duke of Bridgewater employed novice engineer James Bridley to construct a canal to carry coal from his mines in Lancashire to Manchester. Opened in 1761, it was a great success. More canals followed, resulting in a canal network that linked the major industrial centres of the country.

The Etruria Works

BRITAIN 1769

Innovative potter and abolitionist Josiah Wedgwood opened his Etruria factory beside the route of the Trent and Mersey Canal. Though incomplete at the time, Wedgwood saw the value of canal transport to distribute his products. Inside the factory, he introduced methods that greatly increased worker output. Wedgwood broke down the potter's skills – throwing, shaping, firing and glazing – allocating each task to a specialist worker. This was 'division of labour', a method of production later copied in numerous industries.


Celebrated potter Josiah Wedgwood

MAJOR INDUSTRIAL MILESTONES

The heat is on
A coke-fuelled blast furnace is developed by Abraham Darby. Smelting iron ore becomes cheaper, greatly improving production of cast iron goods. **1709**

Shuttle work
Wool mill manager John Kay invents the flying shuttle. The device weaves yarn mechanically rather than by hand. **1733**

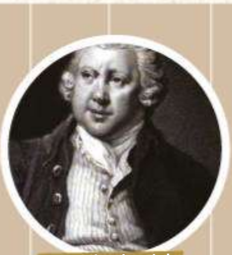
A spinning jenny model at the Museum of Early Industrialisation, Wuppertal, Germany

In a spin
The invention of the spinning jenny is credited to James Hargreaves. **1764**

Engines, engines everywhere
In collaboration with Matthew Boulton, Watt begins the manufacture of steam engines in Birmingham, England. **1774**

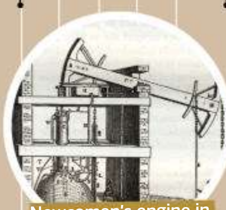
Donkey work
The functions of the spinning jenny and the water frame are combined by Samuel Crompton into one machine. It's called a spinning mule. **1779**

Worlds collide
Richard Arkwright sees the potential of Watt's engines. He is among the first cotton mill owners to use one for production. **1786**


Richard Arkwright

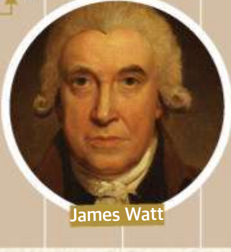
1709 1720 1750 1760 1770 1780

Head of steam
Thomas Newcomen builds his atmospheric steam engine – the first commercially successful such machine – used to pump water from deep coal mines. **1712**


Newcomen's engine in diagram form

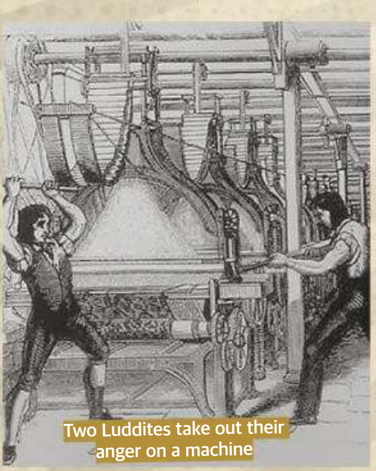
Just add water
Following collaborations with others, Richard Arkwright patents his water frame. It is a spinning device powered by a water wheel. **1769**

Enter James Watt
Adding refinements such as a separate condensing chamber to Newcomen's machine, Scottish inventor Watt designs a more efficient steam engine. **1769**


James Watt

Watt again
Further experiments lead James Watt to adapt his steam engine. He changes its up-and-down pump motion to a rotary motion for more efficiency. **1781**

Loom for improvement
Another textile industry innovation comes from inventor Edmund Cartwright when he makes the power loom to aid weaving. **1785**


Two Luddites take out their anger on a machine

The Luddites

BRITAIN 1811–1815

The Industrial Revolution brought change, but also unrest. Skilled workers facing job losses due to the drive to mechanisation began breaking into factories to smash up machines (see page 36). The mythical Ned Ludd was the supposed Luddite leader. The rioting became so bad that the government passed a law making machine-breaking a crime punishable by death.

SS *Great Britain*, by pioneering photographer Henry Fox Talbot – possibly the first photo of a ship

Brunel's Great Britain

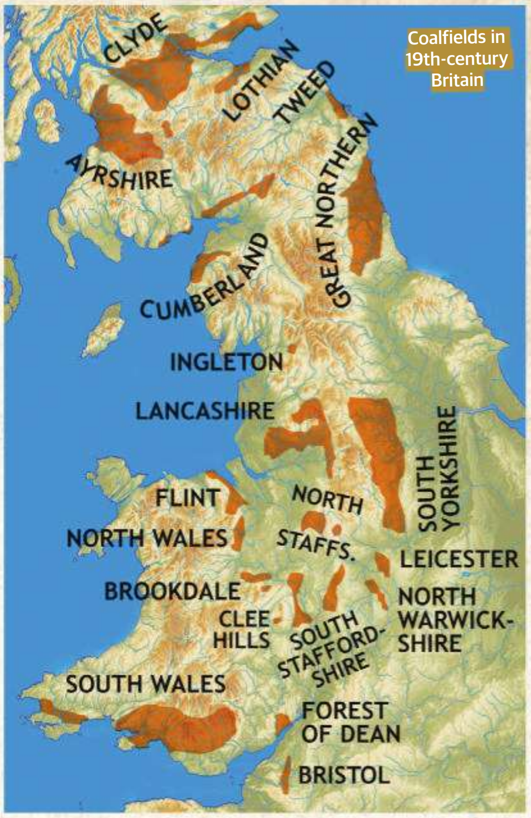
BRITAIN 1843

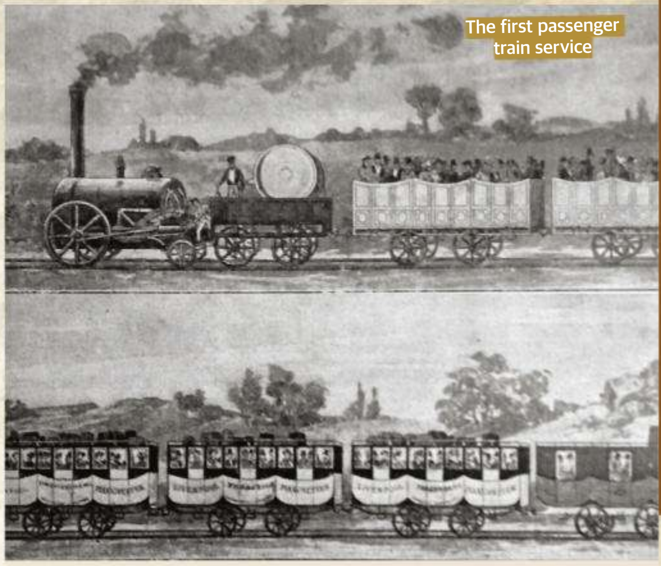
The achievements of civil engineer Isambard Kingdom Brunel were astounding (see page 48). One of his finest was to design the SS *Great Britain*. The vessel is considered to be the forerunner of modern ships because it was the first to combine three elements: it was built of metal, it was powered by engine, and it was driven by a screw propeller. Launched in 1843, it was the longest passenger ship in service until 1854. It survives today as a visitor attraction in Bristol.

FUEL OF THE INDUSTRIAL REVOLUTION

BRITAIN 1900

As the number of steam engines and furnaces grew, the demand for coal increased rapidly. It was in plentiful supply in Britain, though changing from surface extraction to deep-shaft mining was necessary to expand production. Mining coal was dangerous, with mine owners often ruthlessly exploiting a workforce that included women and children until the 1842 Mining Act. Nevertheless, coal production continued to climb – over 9 million tonnes were mined in 1800, that figure rising to over 181 million tonnes by 1900.


Coalfields in 19th-century Britain


The first passenger train service

The train takes the strain

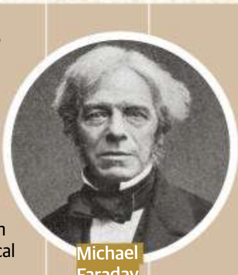
BRITAIN 1830

The 56 kilometres (35 miles) of track between Liverpool and Manchester was the first successful railway line in Britain. Opened in 1830, it was designed to carry paying passengers as well as cargo. It made the transportation of goods and raw materials between industrial Manchester and the seaport of Liverpool cheaper and easier, signalling the end of the line for canal transport.

Across the globe
In the U.S., Eli Whitney makes the cotton gin. The 'engine' separates seeds from raw cotton, which was previously done by hand. **1794**

A cotton gin displayed at Eli Whitney Museum, Connecticut

Spark of genius
The principle of electromagnetic induction is discovered by Michael Faraday (see page 60). His research demonstrates that electricity can become of practical technological use. **1831**


Michael Faraday

Man of steel
The first cost-efficient process for converting pig iron into steel is patented by inventor and engineer Henry Bessemer. **1854**

A shining light
Prolific inventor Thomas Edison refines the light bulb into a reliable, long-lasting light source. His entire electric utility system soon follows. **1879**

One of Edison's first demonstration light bulbs

The Wright stuff
Brothers Wilbur and Orville Wright build and fly the first controlled, powered aeroplane. Orville pilots their Flyer for 12 seconds. **1903**

1790 1800 1820 1840 1860 1880 1900 1908

A replica of Trevithick's locomotive at the National Waterfront Museum, Swansea

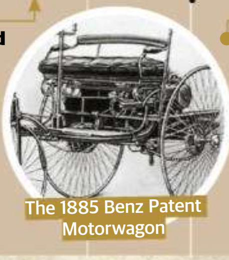
The locomotion
Three years after demonstrating his Puffing Devil steam carriage, Richard Trevithick runs a steam locomotive on rails at a Wales ironworks. **1804**

Need for speed
Robert Stephenson, son of George Stephenson, wins a speed trail contest with his 'Rocket' steam engine. **1829**

A stitch in time
Improving on Elias Howe's lockstitch sewing device, Isaac Singer develops the first truly practical, successful sewing machine. **1851**

Let's talk
Despite claims from Elisha Gray, Scottish-born scientist Alexander Graham Bell is credited with inventing the telephone. **1876**

Driven to succeed
German mechanical engineer Karl Benz, spurred on by wife Bertha, develops the first practical car powered by an internal combustion engine. **1885**


The 1885 Benz Patent Motorwagon

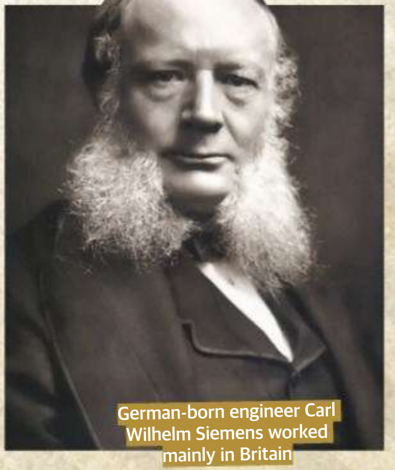
Mass production, mass consumption
The Model T car is manufactured by Henry Ford. It is affordable for many due to assembly-line mass-production methods. **1908**

Part of Babbage's analytical engine displayed at the Science Museum, London

The first computer

BRITAIN 1837

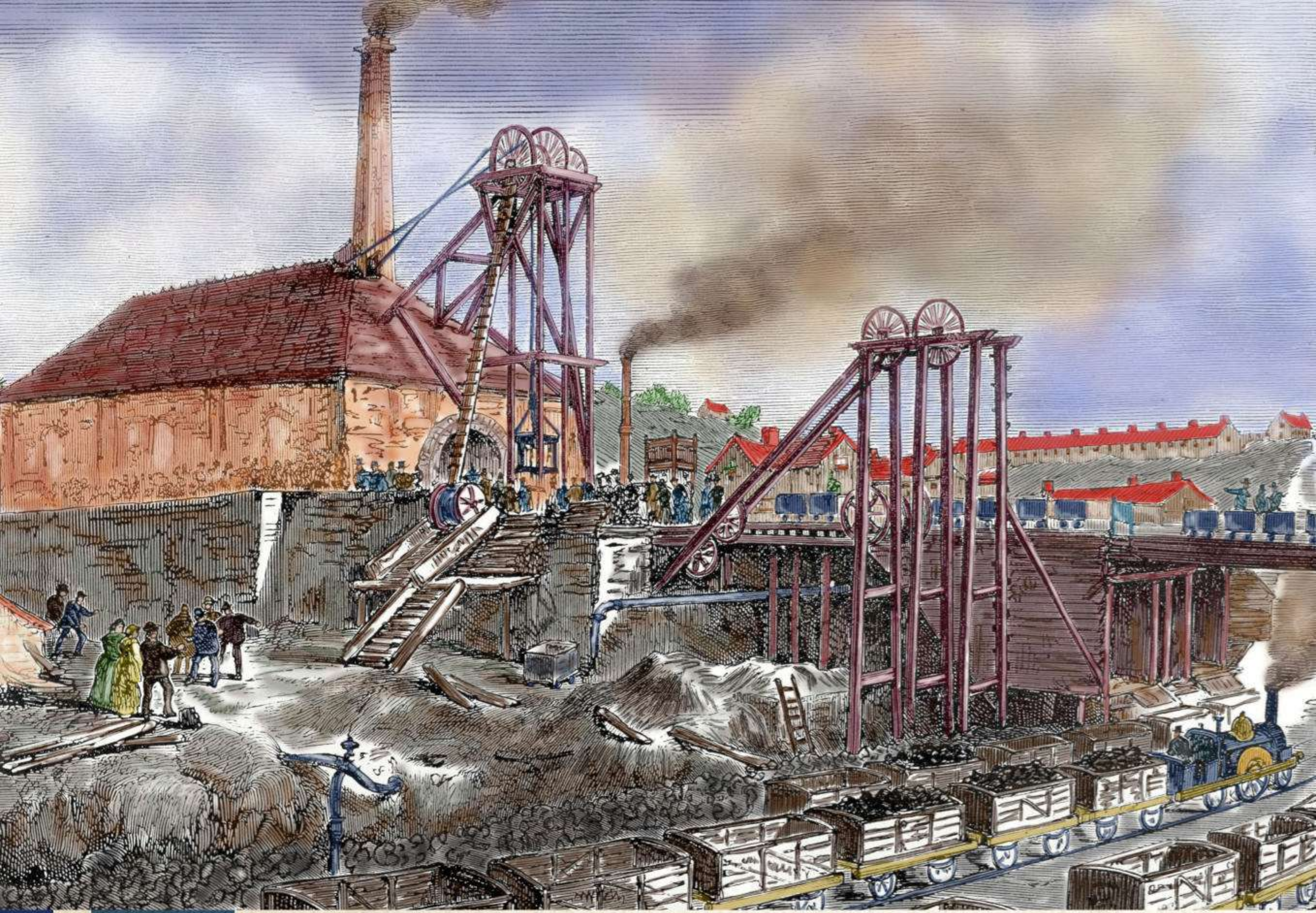
Many engine designs from the Industrial Revolution were never built. Perhaps the most astonishing device not constructed at the time was the analytical engine of Charles Babbage. His vision was for a huge brass, steam-powered, mechanical digital computer. Only much later, when modern-day computer designers began development, did it become clear that Babbage had anticipated almost every aspect of their work.


German-born engineer Carl Wilhelm Siemens worked mainly in Britain

Bulk steel production

BRITAIN 1865

Steel output increased greatly when Bessemer's converter method was improved by the open-hearth process. Devised by Carl Wilhelm Siemens and developed by Pierre-Emile Martin, it was easier to control and allowed for large amounts of scrap iron and steel to be melted and refined. Bulk steel production from the Siemens-Martin process meant a greater use of steel in construction.



A combination of invention and raw materials helped kick off the Industrial Revolution

WHY BRITAIN?

The fascinating factors that took this island nation to the forefront of global industrialisation

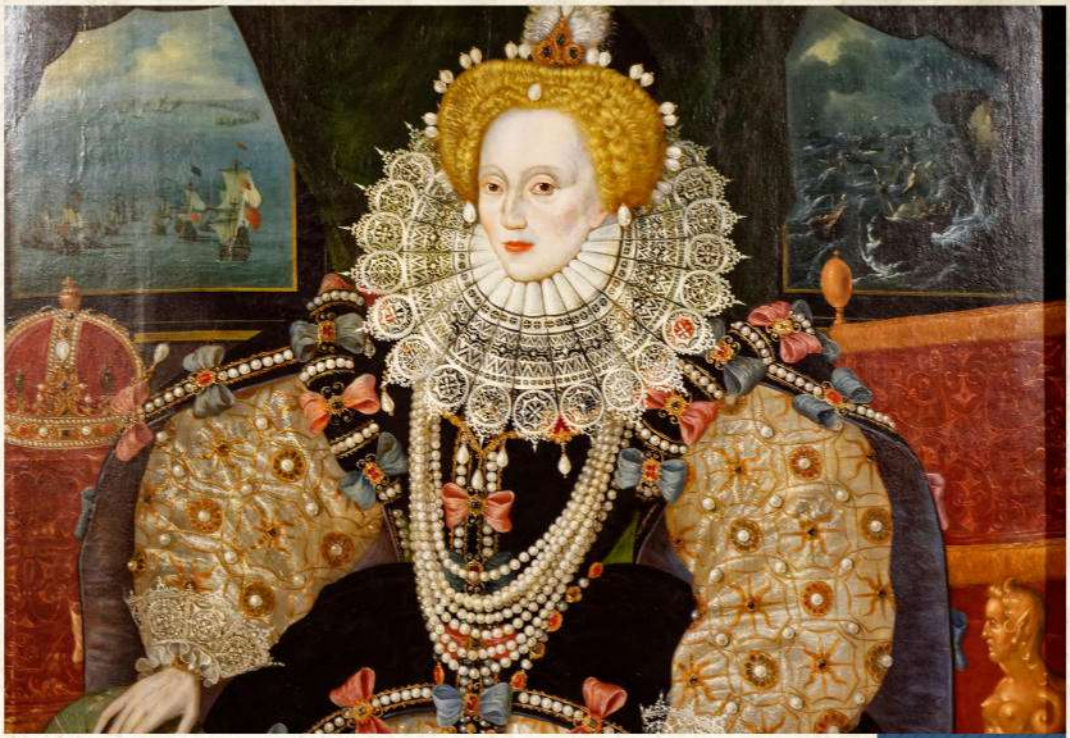
Written by Alex Hennessy

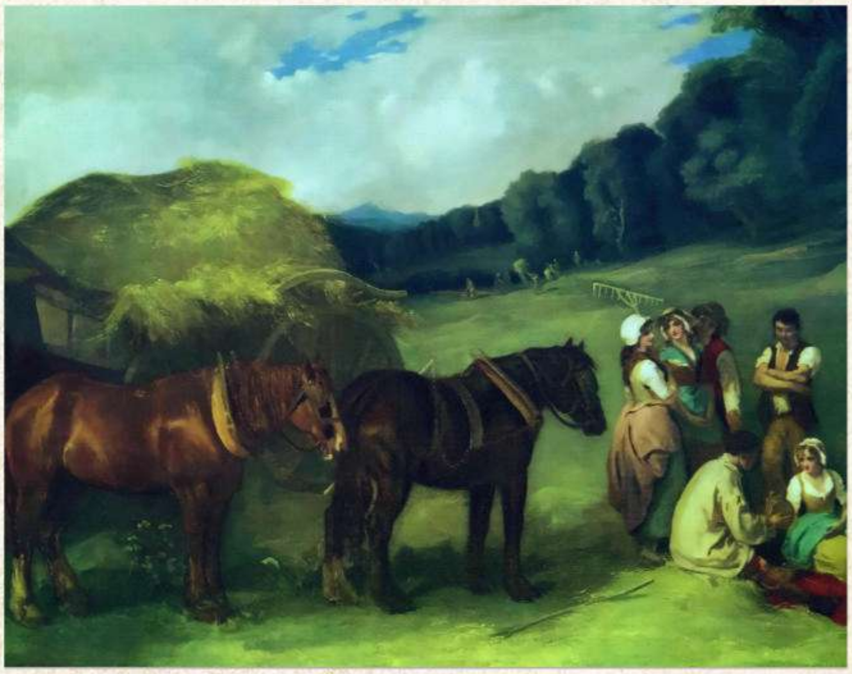
On 31 December 1600, Queen Elizabeth I incorporated the East India Company as her very last order of business for the year. Just seven years later, John Smith's Virginia Company established the first permanent British colony in North America – Jamestown. The first glimmers of the Industrial Revolution were still decades away, but one of its key factors had just been decided.

When considering the Industrial Revolution, curiosity naturally leads to a crucial question: why did it happen in Britain? What were the unique circumstances that meant this relatively small island, separated from mainland Europe, would provide the backdrop for innovation and progress that would change the world forever? The impact of the British Empire, built upon the foundations laid in Queen Elizabeth's reign, was certainly one contributing factor to a period of rapid change.

Britain's numerous crown colonies formed a powerful international trade network that could be exploited for its own advancement, often at the expense of the native communities it sprung itself upon. Today, some hold the British Empire in high esteem as a great country's finest achievement, while others decry its exploitative record and shameful links with slavery. In the context of the Industrial Revolution, its value was clear. Not only did Britain's colonies open up new export markets for the country, they also afforded unprecedented access to huge stores of raw materials with the potential to greatly increase Britain's economic output. The Americas provided cotton, tobacco and sugar, while Britain plundered Australia's stores of gold and wool. From India, Britain took tea and spices, and the gold and diamonds extracted from the African colonies brought Britain more riches.

While taking advantage of resources from her colonies, Britain was also making the most of the new markets these colonies presented. Britain was able to sell more of its manufactured goods through its colonies, with textiles, furniture and tools all selling well.





Elizabeth I, whose reign oversaw the beginnings of Britain as an imperial power

A vision of rural work in the 18th century - *The Hay Cart* by Francis Wheatley

This large and expanding audience for Britain's goods naturally encouraged more manufacturing back on British soil, thereby creating employment opportunities and driving innovation that led to the Industrial Revolution's greatest inventions.

Due in large part to its global aspirations, it was also a time of great change for working people in Britain. In the span of a century many people were redistributed from jobs working the land or hand-crafting goods for sale to jobs in cities and factories. The new jobs demanded shifts of up to 16 hours per day, with men, women and children all put to work. The population was growing and working harder than ever. They needed sustenance, and Britain's agricultural revolution rose to meet the challenge of feeding them. Population growth had previously been stunted by the inability to grow enough food for a larger number of people. However, in 1750, with a population of 5.7 million people, England found the answer to feeding more mouths. By 1850, England's population stood at 16.6 million.

This significant agricultural progress was possible thanks to a number of factors. One was the intensification of crop growing (growing more food in the same amount of space). In addition, land was reclaimed, including woodlands, pasture and the fenlands of east England, which were drained for farming. With this new land, farmers began to use crop rotation to their advantage. One well-

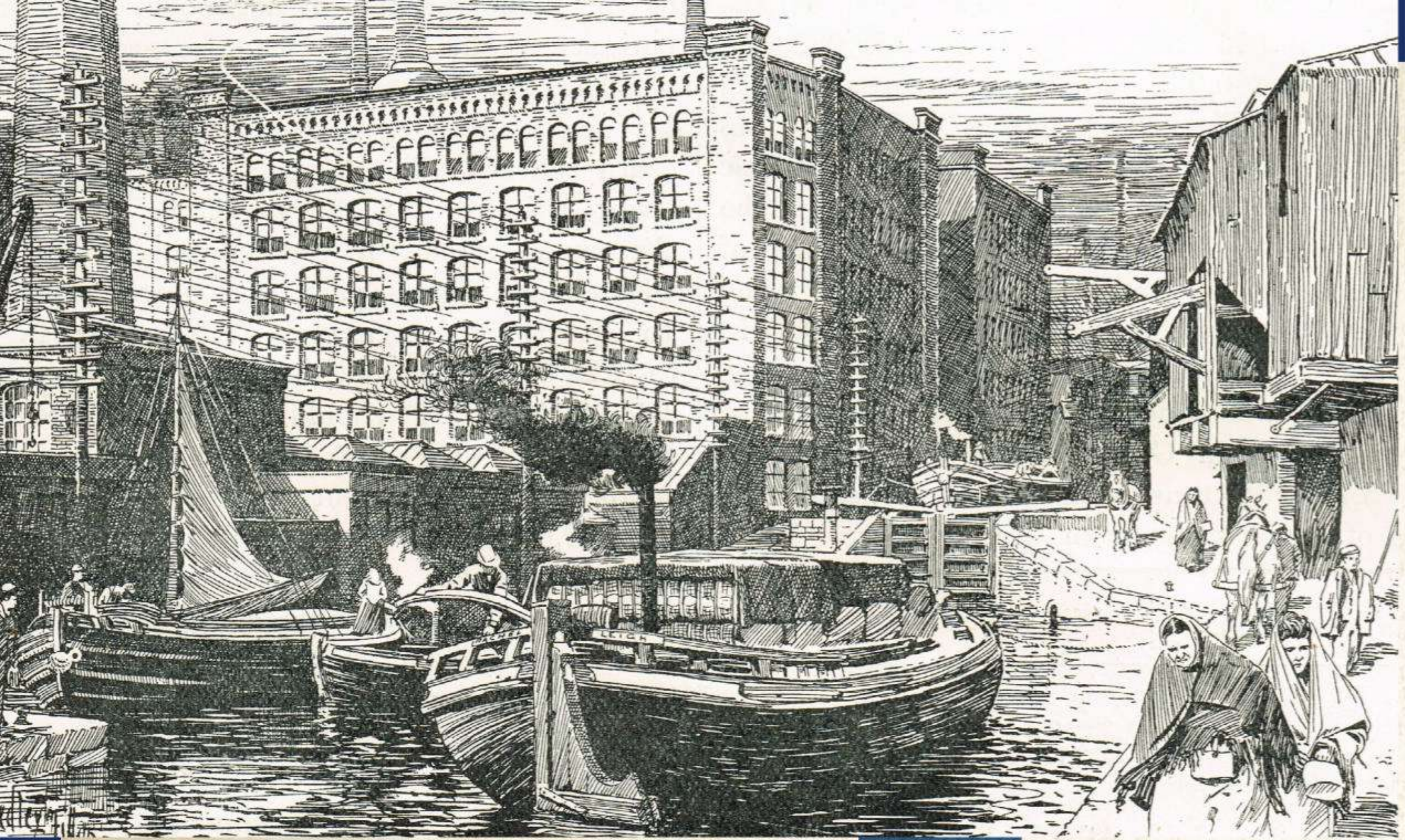
> "DUE IN LARGE PART TO ITS GLOBAL ASPIRATIONS, IT WAS A TIME OF GREAT CHANGE FOR WORKING PEOPLE IN BRITAIN"

IRONS IN THE FIRE

It was in the aptly named town of Coalbrookdale that Abraham Darby discovered coal could be used for smelting iron. Darby had been working with brass until 1708, when he repaired an iron-making furnace. This seems to have sparked a desire to improve the process, and in 1709 he pioneered smelting iron using coal in a blast furnace. The iron was then poured into moulds to make ingots, which could be distributed, used for steelmaking or worked upon in a finery forge to make items from wrought or cast iron.

Others had tried to move to coal before Darby; the process had previously relied on wood charcoal for heating, but with increasing pressures on wood supplies, and the ready availability of coal, being able to use the fuel for this purpose was a breakthrough. The charcoal method had also been less efficient, making iron products more expensive. This in turn had an effect on how much progress could be made with the material.

As such, perhaps the most impactful outcome of this revolution in iron was its use in the development of steam engines. In fact, by the mid- to late 1700s, Newcomen's steam engines across the country were using cylinders cast at Darby's factory in Coalbrookdale as they pumped water out of mines.

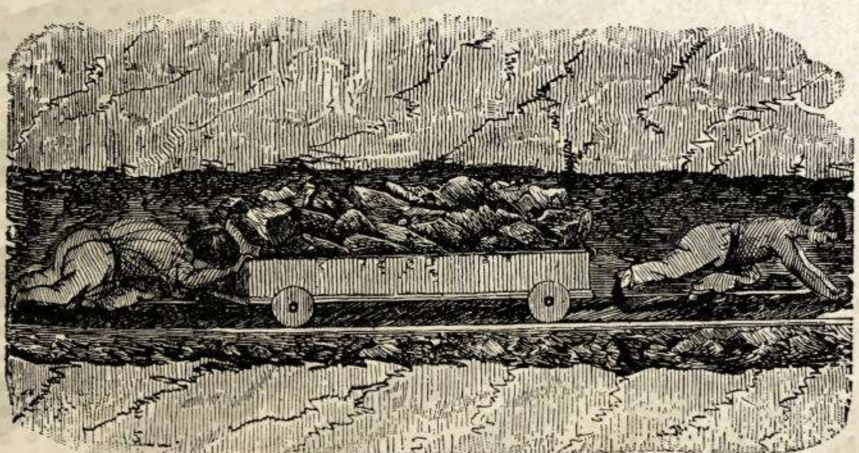


Workers had to move from their rural homes to the expanding cities to seek employment

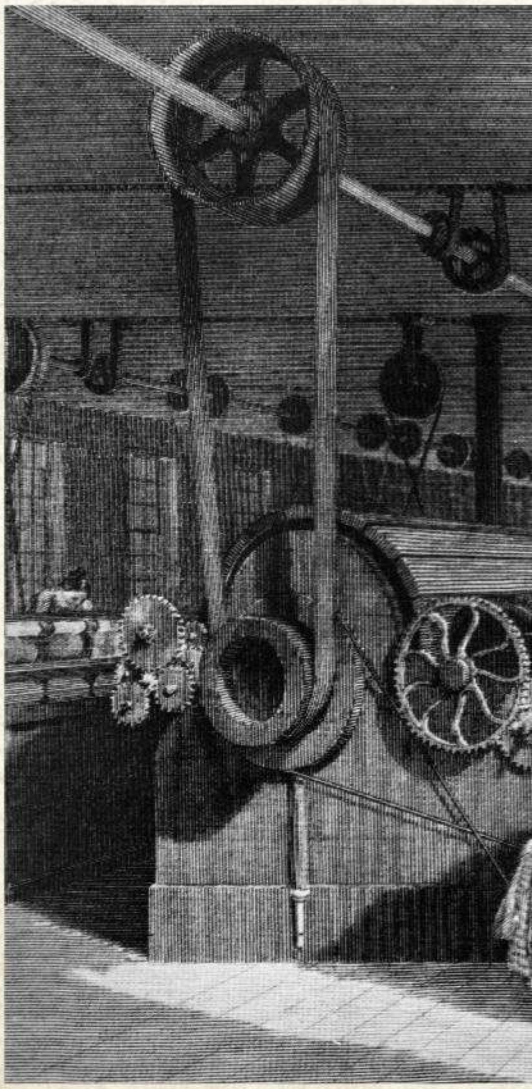
known rotation system involved turnips and clover. Turnips could grow on fallow land set aside to be ploughed to remove weeds, as the weeds between rows of turnips could be removed by hoe. Clover was useful as it replenished the soil's stocks of nitrogen, a key component for healthy crops. Its widespread use from the mid-17th century meant that by the 19th century agricultural soil across England was well stocked with this vital nutrient.

Another factor in the agricultural revolution was more efficient use of better-quality seeds. The seed drill was famously perfected by Jethro Tull in 1701. This horse-drawn device sowed seeds economically into neat rows. Until this time, seed had been sown by hand, a much less reliable method. However, Tull first publicised the drill's benefits in a treatise in 1731 and uptake of the equipment grew steadily over the following century, so its impact leading up to the Industrial Revolution is likely to have been slight. Nonetheless, Britain was able to sustain immense population growth for the first time with the other improvements made to agriculture. The fact that it did so was another key driver of the Industrial Revolution.

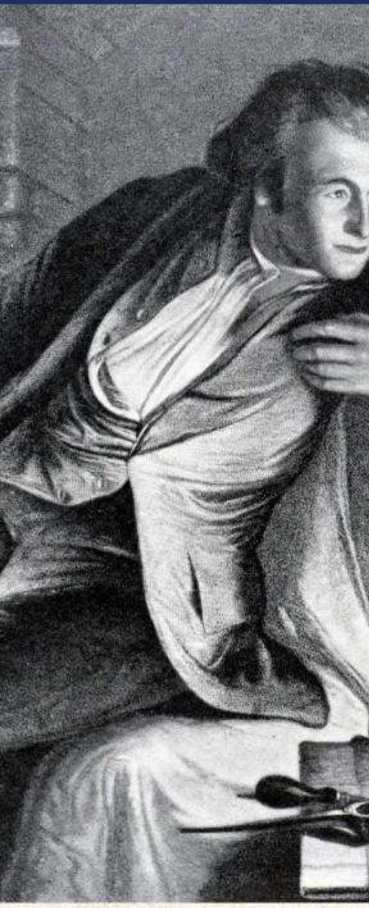
While Britain was prospering from efficient use of its land, it also profited because of what was underneath it: coal. This wasn't a new discovery – coal had been used as fuel for thousands of years. But its true potential was only unlocked at the start of the Industrial Revolution. This was perhaps the most significant catalyst for industrialisation. Britain had vast stores of coal waiting to be mined in the North East of England, the Midlands, South Wales and central Scotland. In the



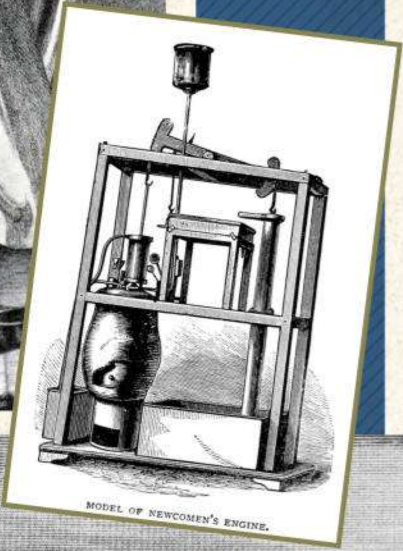
A visceral depiction of coal mining in the 19th century



Workers in a textile factory in northern England in the 18th century



A portrait of James Watt, a Scottish inventor who improved upon the Newcomen steam engine design


MODEL OF NEWCOMEN'S ENGINE.

Newcomen's steam engine, invented in 1712, was able to mechanically remove water from mines

early 1700s, around 3 million tonnes of coal were mined annually. This increased ten-fold by the 1830s.

Such an ample supply meant that coal was relatively cheap in Britain compared to other countries without the same coal stores and mining infrastructure. Meanwhile, labour was comparatively expensive. This dynamic of cheap fuel and expensive labour incentivised inventors and entrepreneurs to develop ways to harness the power of coal to replace workers. This drive for efficiency led to inventions such as the steam engines devised by Thomas Newcomen and improved upon by James Watt. For those like Newcomen and Watt, who had an aptitude for invention, the incentive of monetary gain was protected by robust patenting laws. In countries without this safeguard inventors risked their designs being shamelessly copied, negating any real benefit for their hard work. But by protecting the rights of the inventor, Britain's legal system provided an added boost to the race to innovate and make manufacturing more efficient.

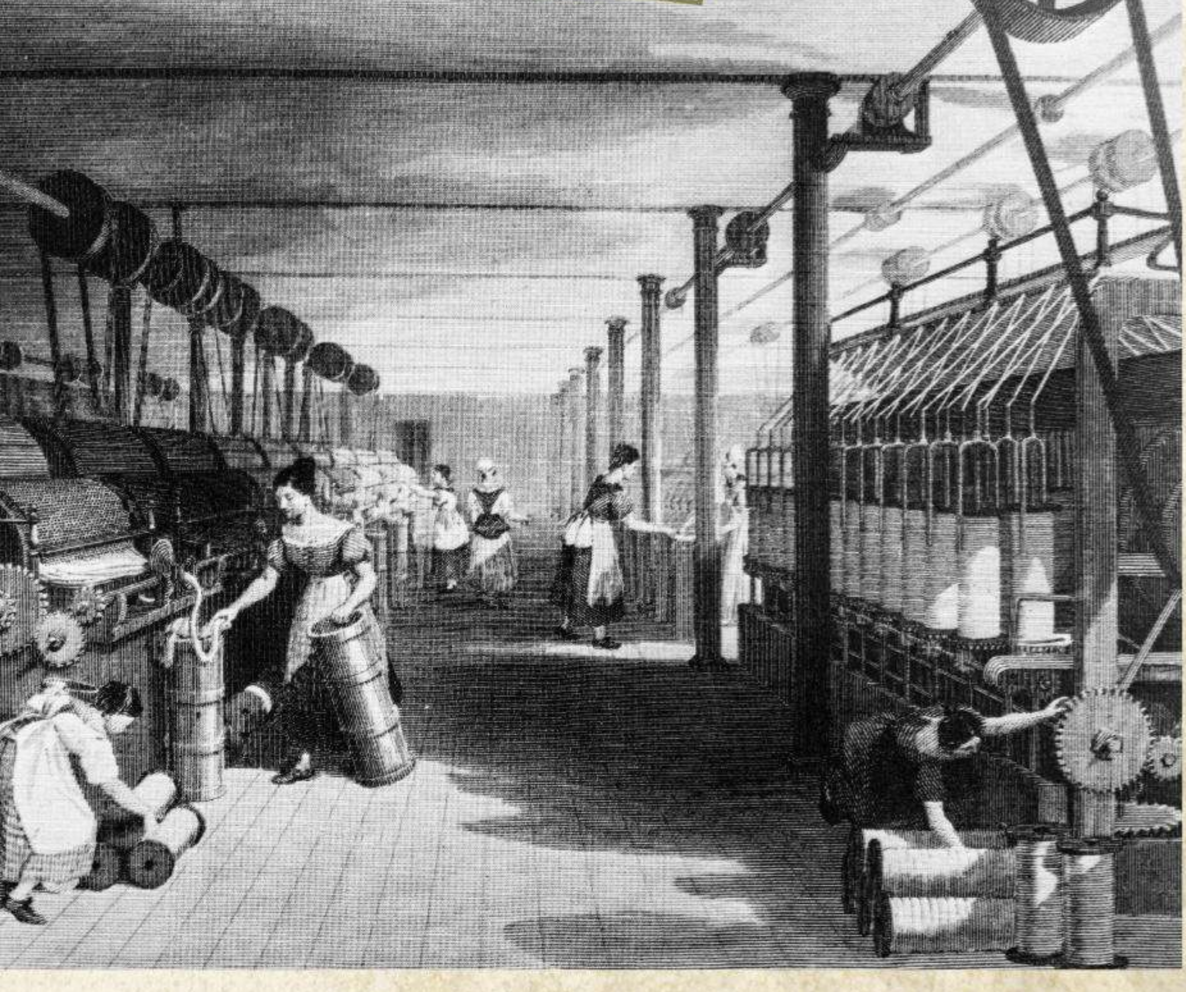
> "THE ABUNDANCE OF COAL GAVE INVENTORS AND ENTREPRENEURS THE MEANS TO REDUCE COSTS"

Newcomen's steam engine, invented in 1712, was used primarily to remove water from mines, which had previously been achieved using buckets on a pulley system attached to horses – a manual and resource-heavy operation. Newcomen's engine streamlined the process but needed to use a lot of coal to do it. Watt's engine improved efficiency by using a separate condenser, negating the need to heat and cool the engine's cylinder repeatedly. Watt's engine also enabled more extensive use of the machine, including powering rotary mechanisms for cotton mills, for example.

The other key use for coal in industrial terms was the use of coke – coal that has been heated to a high temperature in a sealed environment to remove impurities. Coke was used to make pig iron via a method perfected by Abraham Darby (see page 9). Using a coal by-product in iron production not only enabled more efficient manufacture of iron and steel goods, but it also sped up progress in inventions like the steam engine, which required large amounts of quality metal at a more affordable price.

Within Europe, Belgium, France and Germany had stores of coal to mine – which they began to exploit in a similar fashion to Britain – but not until the 19th century. And while other European countries were forging empires across the world, the British Empire was the largest and most successful (in colonial terms). In the eyes of many historians, these were the two deciding factors from which all other components stem: the success of the British Empire drove industrialisation to feed the growing demand for goods, while an abundance of coal gave inventors and entrepreneurs the means and incentive to reduce costs (and make a fortune) if they could harness its power.

Of course, there is no definitive answer to the question of Britain's primacy in industrialisation. Others have attributed it to foundations laid in the centuries leading up to the Industrial Revolution, through a relatively stable political system, well-developed commercial law and an emphasis on logic and science thanks to the Age of Enlightenment. It seems most likely that all of these factors, combined with the spark of invention that comprises luck and intellect, combined at the right time. Thus began the Industrial Revolution on British soil.



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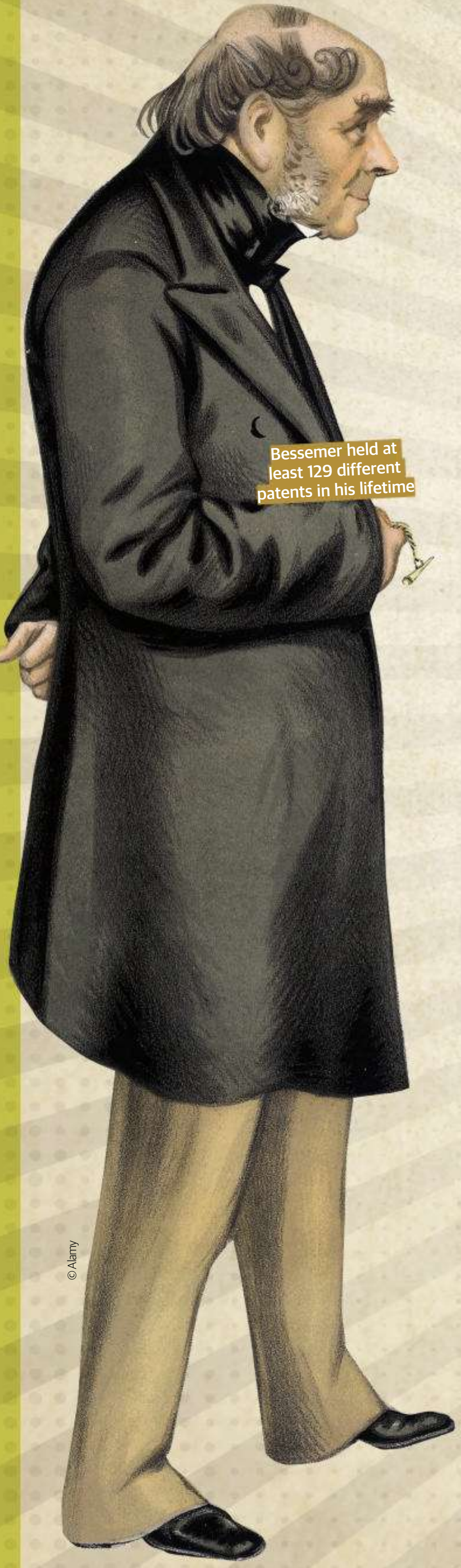
INDUSTRIAL PIONEERS

Meet the giants of industry who transformed a land of fields into a nation of iron and big business



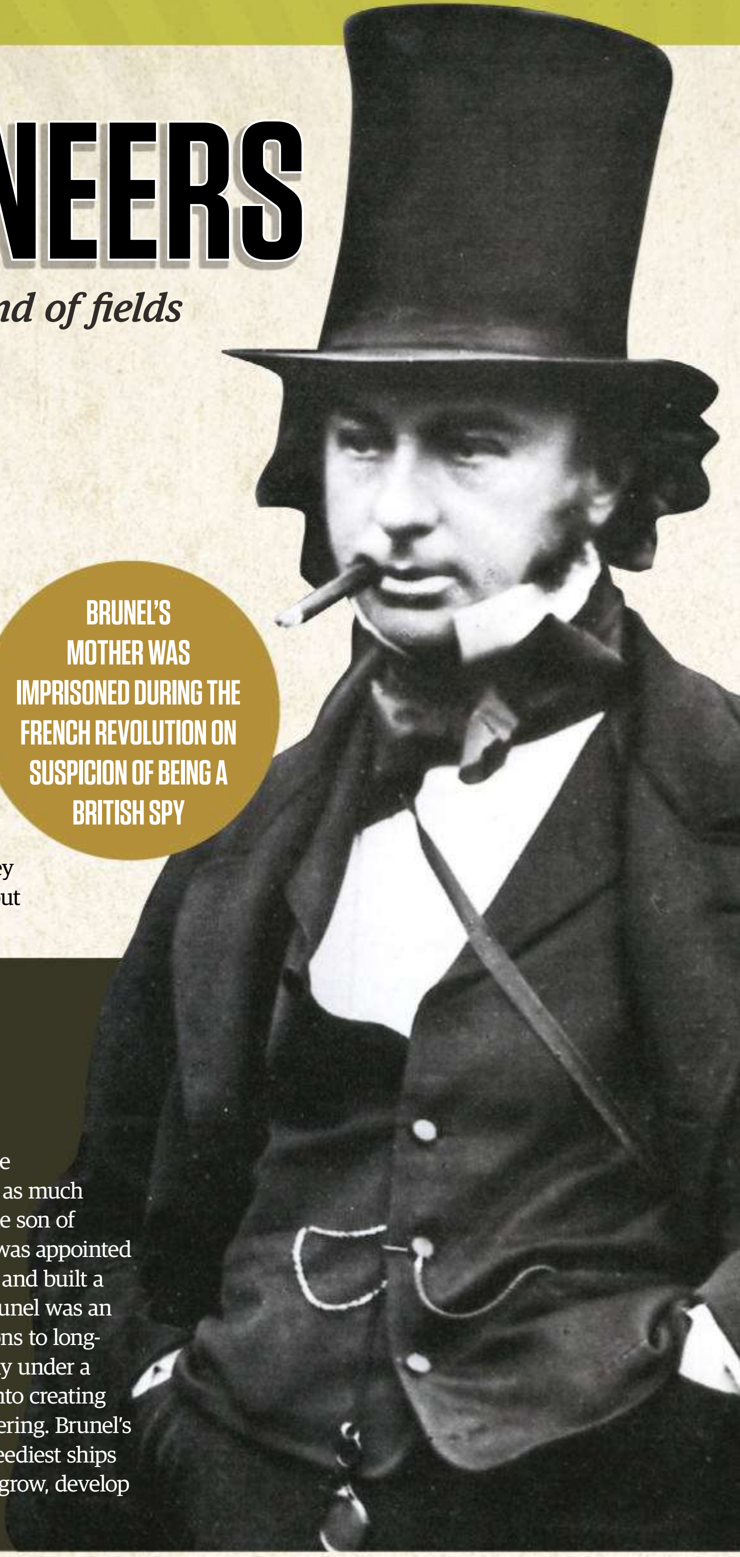
Bessemer held at least 129 different patents in his lifetime

© Alamy

HENRY BESSEMER

ENGLISH 1813–1898

The material that defines the Industrial Revolution is undoubtedly steel. It was not until a particular process was developed that steel was able to be mass-produced. This process is known as the Bessemer process, and the man behind it was Henry Bessemer. Bessemer's process involved creating steel by using molten pig iron, which allowed for cheaper production. This innovative development enabled the expansion of many key industries such as the railway lines and was key to industrial development not only in Britain but America as well.



BRUNEL'S MOTHER WAS IMPRISONED DURING THE FRENCH REVOLUTION ON SUSPICION OF BEING A BRITISH SPY

ISAMBARD KINGDOM BRUNEL

ENGLISH 1806–1859

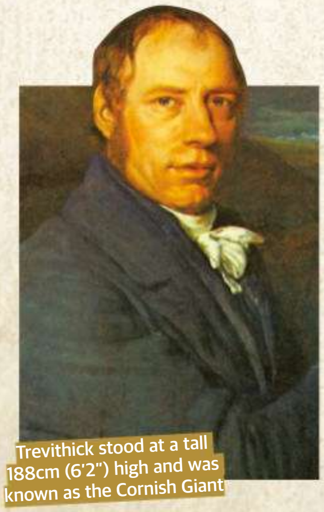
There are many names associated with the development of railways, but none carry as much weight as Isambard Kingdom Brunel. The son of French engineer Mark Isambard Brunel, he was appointed chief engineer of the Great Western Railway and built a network of tunnels, bridges and viaducts. Brunel was an engineering pioneer, achieving many solutions to long-standing problems, such as building a railway under a navigable river. He also extended his skills into creating steamships and revolutionised naval engineering. Brunel's innovation led to the biggest bridges and speediest ships the world had ever seen, allowing Britain to grow, develop and trade in groundbreaking new ways.

RICHARD TREVITHICK

ENGLISH 1771–1833

Hardly a star student, Trevithick struggled at school but went on to become a major pioneer of the Industrial Revolution. Contemporary steam engines were low-pressure, but when Trevithick became engineer at the Ding Dong Mine in 1796 he pioneered the use of high-pressure steam. Although he was not the first to think of high-pressure steam, he was the first in the country to make it work, and his engines were used for raising ores from mines.

Trevithick also built a full-scale working steam locomotive. However, Trevithick died in poverty, with local factory workers raising money for his funeral.



Trevithick stood at a tall 188cm (6'2") high and was known as the Cornish Giant

JAMES HARGREAVES

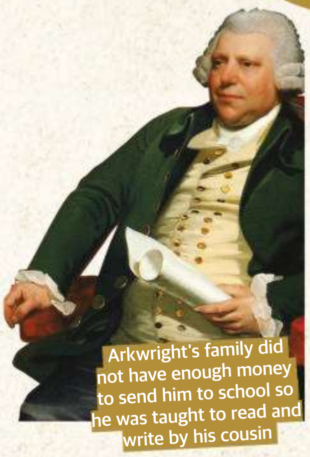
ENGLISH 1720–1778

The mechanisation of the textile industry was a major force behind the Industrial Revolution. James Hargreaves contributed massively to this with his creation of the spinning jenny. When the demand for cotton yarn outstripped the capabilities of the one-thread spinning wheel, Hargreaves created a multi-spindle spinning frame that could work eight or more spools at once. He set up shop in Nottingham, where his invention quickly found success and popularity.

RICHARD ARKWRIGHT

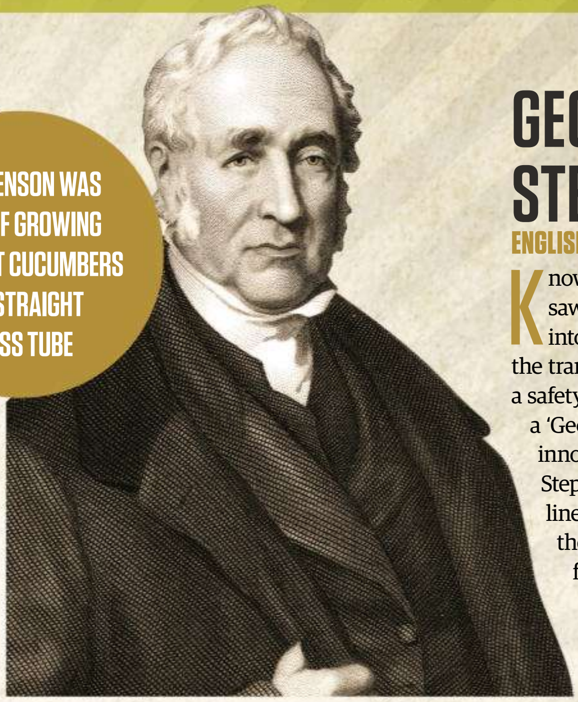
ENGLISH 1732–1792

A figure so influential he is known by many as 'the Father of the Industrial Revolution', Arkwright's inventions and ingenuity helped to usher in the industrial age. Arkwright developed new processes in yarn manufacture and was the first to use the steam engine to power textile machinery. Arkwright's innovation in combining



Arkwright's family did not have enough money to send him to school so he was taught to read and write by his cousin

STEPHENSON WAS FOND OF GROWING STRAIGHT CUCUMBERS IN A STRAIGHT GLASS TUBE



GEORGE STEPHENSON

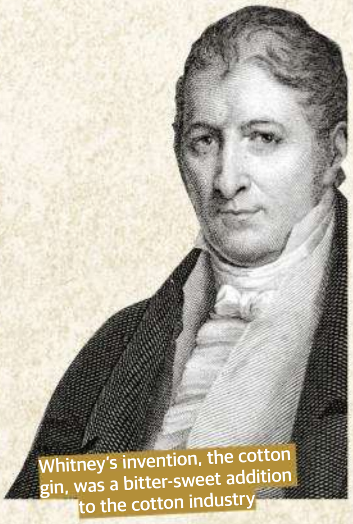
ENGLISH 1781–1848

Known as the 'Father of Railways', Stephenson saw Britain develop from a land of farms into one of factories, contributing hugely to the transformation. While Stephenson created a safety lamp for use in coal mines known as a 'Geordie', he is remembered most for his innovations on the railway. A skilled engineer, Stephenson created the first public railway line to use steam locomotives (and created the locomotives as well), even driving the first train. The success of his locomotive 'Rocket' inspired countless constructions of railway lines and locomotives across the country, helping make Britain the wealthiest country in the world.

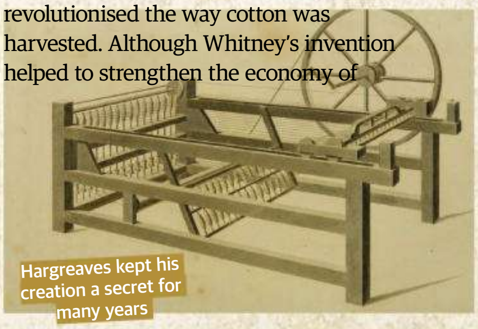
ELI WHITNEY

AMERICAN 1765–1825

While the Industrial Revolution was blasting full steam ahead in Britain, America, too, was experiencing the start of its own industrial revolution, and one of the key figures behind it was Eli Whitney. It was Whitney's invention of the cotton gin that completely revolutionised the way cotton was harvested. Although Whitney's invention helped to strengthen the economy of



Whitney's invention, the cotton gin, was a bitter-sweet addition to the cotton industry

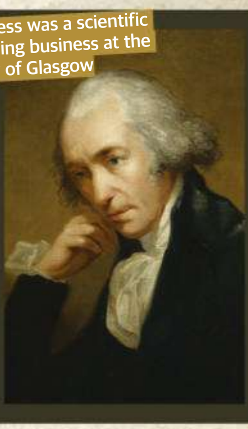


Hargreaves kept his creation a secret for many years

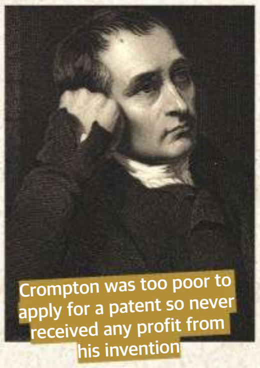
JAMES WATT

SCOTTISH 1736–1819

Although the unit of measurement 'Watt' is named in his honour, it was his improvements in steam technology that brought Watt fame and success. While working as an engineer, Watt was sent a steam engine to repair. When reassembling it he devised a way to make it more efficient by designing a separate condensing chamber that reduced steam loss. With his new design, Watt began to manufacture engines, and his company soon became the most important engineering firm in the country. The efficiency brought by Watt's machines was fundamental in taking the Industrial Revolution worldwide.



Watt's first business was a scientific instrument-repairing business at the University of Glasgow



Crompton was too poor to apply for a patent so never received any profit from his invention

SAMUEL CROMPTON

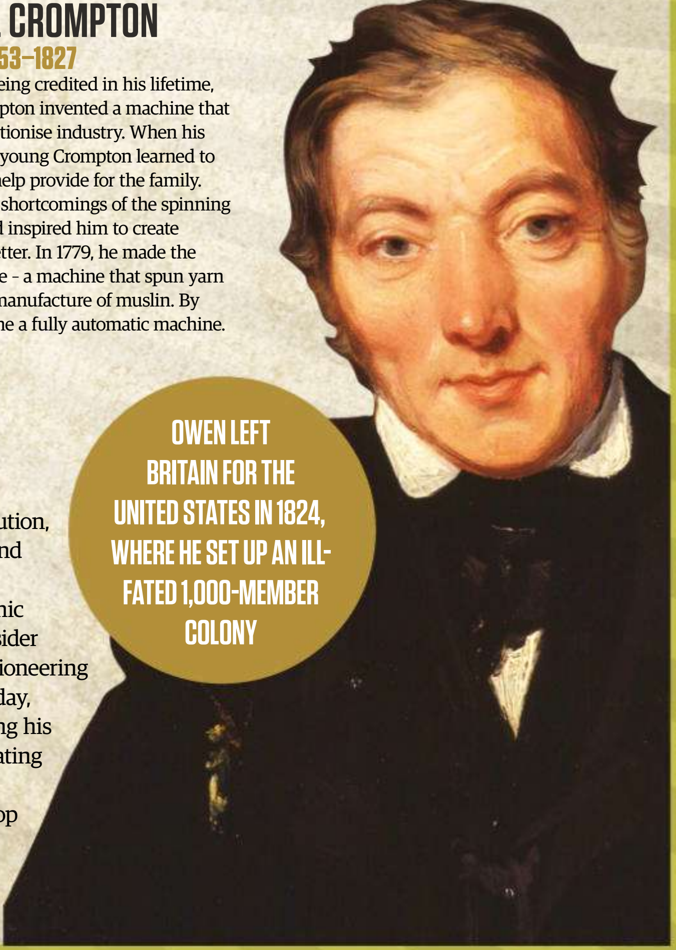
ENGLISH 1753–1827

Despite not being credited in his lifetime, Samuel Crompton invented a machine that helped revolutionise industry. When his father died, a young Crompton learned to spin yarn to help provide for the family. However, the shortcomings of the spinning jenny he used inspired him to create something better. In 1779, he made the spinning mule - a machine that spun yarn used for the manufacture of muslin. By 1834, it became a fully automatic machine.

ROBERT OWEN

WELSH 1771–1858

With the rapid increase of industrialisation during the revolution, demand was high, pay was low and working conditions were terrible. This prompted a period of social and economic reform, and one of the first men to consider worker welfare was Robert Owen. His pioneering work included shortening the working day, introducing a minimum wage, improving his workers' living conditions and even creating the first national union. While Owen's union collapsed, his ideas helped develop the modern cooperative movement.



OWEN LEFT BRITAIN FOR THE UNITED STATES IN 1824, WHERE HE SET UP AN ILL-FATED 1,000-MEMBER COLONY

THE STEAM ENGINE

For centuries the steam engine powered British industry, and even today steam plays a big part in the generation of electricity. We take a look at the men behind these major inventions

Until the start of the 18th century, machines were powered by muscle, water or wind, but steam power provided the potential for growth and flexibility on a mass scale. Steam engines facilitated the birth of large factories as production moved from rural riverbanks to industrial towns, leading to the formation of the cities we know today.

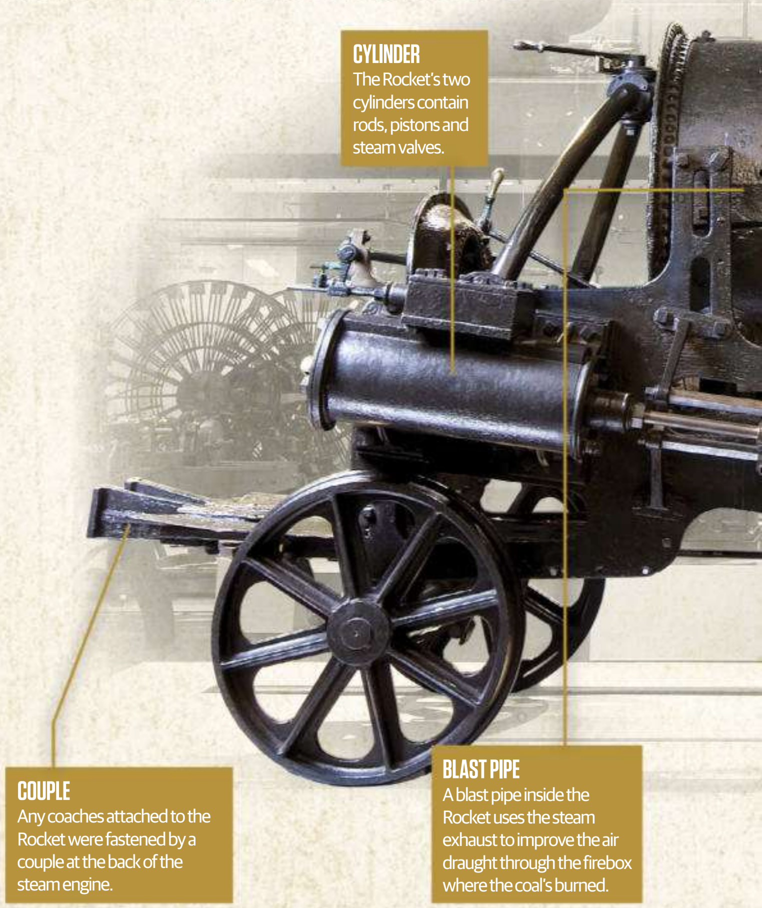
Steam power had been around for generations, but it wasn't until 1698 that its application in industry started to be appreciated. Military engineer Thomas Savery created a patent for the raising of water by "the impellent force of fire", the first noted design of a steam pump. In 1712, Thomas Newcomen continued Savery's work and constructed the first successful steam engine, the atmospheric engine. Its purpose was to rid coalmines of floodwater, allowing miners to reach new depths. It was considered so efficient for its time the design wasn't altered for six decades and the template was copied up and down the country.

British engineer James Watt came to largely represent the face of the steam movement because his many patents prevented other engineers from furthering the progression of steam-powered machinery until they expired in 1800, at which point a hungry new league of engineers took up the baton. Richard Trevithick pioneered 'strong steam' (steam at high pressure), meaning vapour could be 'compounded' and used repeatedly in a series of cylinders. Such a method was used in ships, on railways and in agriculture, inspiring new vehicles and machines, from self-propelled steam boats and carriages to traction engines for the land and engine houses for grinding and processing grain.

By 1820, steam locomotives were commonplace, and in 1830 the Liverpool and Manchester Railway opened as the world's first inter-city passenger railway, engineered by George Stephenson and utilising locomotives that were designed by his son, Robert, including the magnificent Rocket.

Towards the end of the 19th century inventors found new ways to maximise steam efficiency, and in 1884 Charles Parson's steam turbines opened a whole new world of possibilities. Today steam-powered engines are no longer in widespread commercial use, but some of their applications can still be seen, from the production of electricity to underwater jet engines.

Robert Stephenson's Rocket was acquired by the Science Museum in the 1860s



CYLINDER
The Rocket's two cylinders contain rods, pistons and steam valves.

COUPLE
Any coaches attached to the Rocket were fastened by a couple at the back of the steam engine.

BLAST PIPE
A blast pipe inside the Rocket uses the steam exhaust to improve the air draught through the firebox where the coal's burned.

A HISTORY OF STEAM...

1698
Thomas Savery patents his machine for the raising of water by the "impellent force of fire", the first design of a steam pump.

1712
Thomas Newcomen builds the first practical steam engine. It is erected near Dudley Castle in Staffordshire.

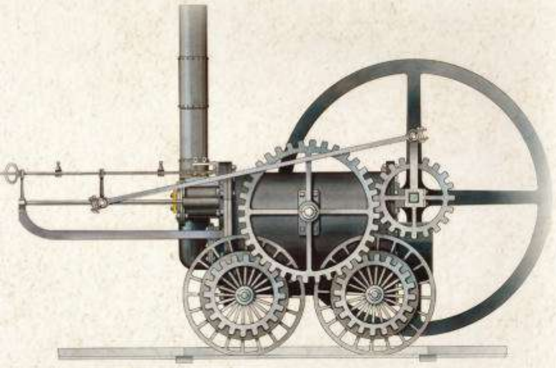
1733
Savery's patent expires, meaning more Newcomen engines can be built without fear of committing an infringement.

1769–1800
James Watt dominates steam-engine design and improvement. The Watt steam engine is the first to use steam at a pressure above that of atmospheric to drive the piston.

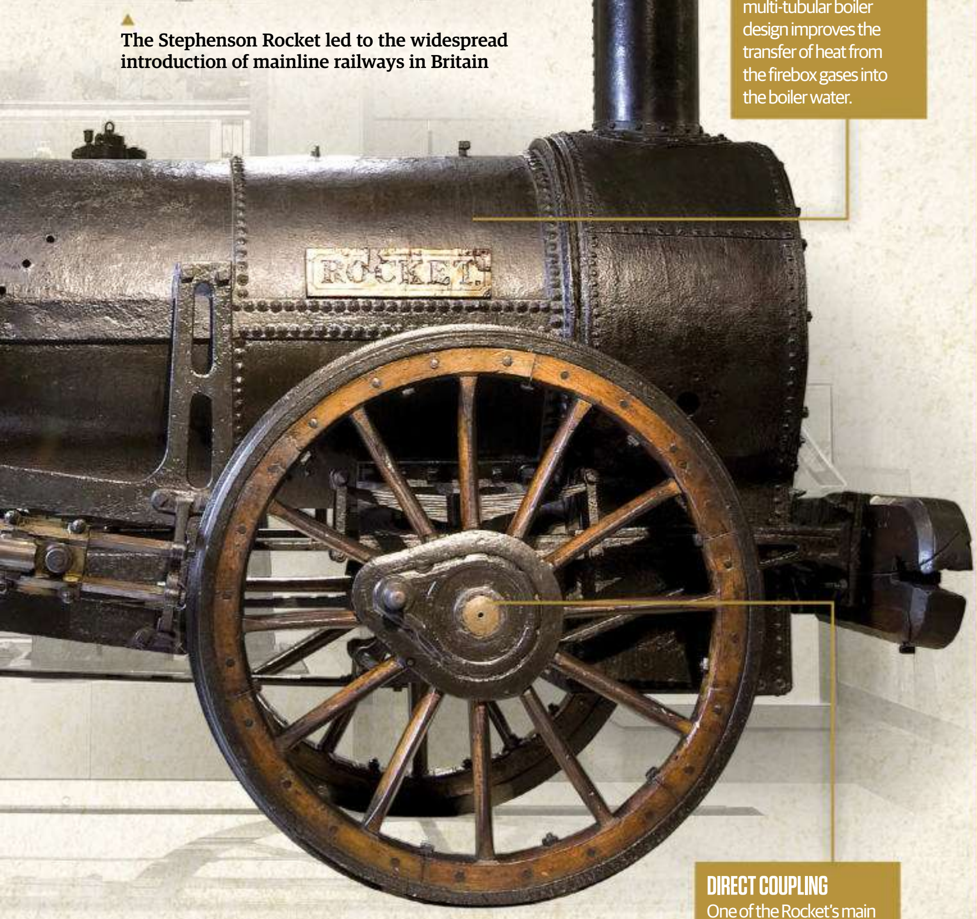
1804
Arthur Woolf builds a compound engine that matches the work of Watt's machines using half the fuel.

1806
Richard Trevithick becomes the first British engineer to use high-pressure 'strong' steam. The machine revolutionised transport.

"IN 1884 CHARLES PARSON'S STEAM ENGINES OPENED UP A WHOLE NEW WORLD OF POSSIBILITIES"



The Stephenson Rocket led to the widespread introduction of mainline railways in Britain



CHIMNEY
Smoke created in the firebox is passed to a smokebox beneath the chimney. This smoke is then released into the atmosphere.

MULTI-TUBULAR BOILER
The Rocket's multi-tubular boiler design improves the transfer of heat from the firebox gases into the boiler water.

DIRECT COUPLING
One of the Rocket's main features is direct coupling, which uses connecting rods to link the pistons to the driving wheels.

THE SCIENCE MUSEUM'S BEN RUSSELL

We spoke to Ben Russell, the curator of mechanical engineering at the Science Museum, to find out more about the early steam industry

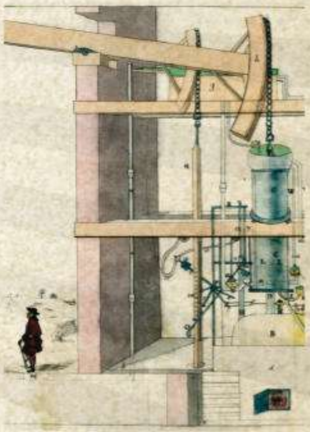
All About History: Why was steam so significant to British industry?
Ben Russell: Using a waterwheel to drive stuff only gets you so far. If Britain was to become this huge industrial nation, it needed a way of getting power to wherever people needed it, and steam was the way of providing that.

AAH: Why is Stephenson's Rocket such an icon of the steam age?
BR: The Rocket was built for the Rainhill Trials in 1829, intended to choose the locomotive design for the Liverpool Manchester Railway. It was competing against a number of other engines, but it won because it packaged together a whole series of innovations in engine design and in doing so laid the basis for locomotive design up until the 20th century.

AAH: What is the importance of Newcomen's steam pump?
BR: If we didn't have enough coal the Industrial Revolution would have faltered early on [we might never have become the industrial capital of the world]. This development depended on making a mine deep enough to get to deep coal reserves without the mine filling with floodwater. For the first time the engine was capable of providing a huge amount of power to keep the mines free of floodwater so they could get to that coal and produce sufficient coal to keep the industry ticking over.

AAH: How significant was James Watt's contribution to the history of steam power?
BR: Watt died in 1819 and even then he and his son had spent a lot of time building this 'Watt myth' that he's the bloke who created modern Britain. There was a lot of myth-making and many engineers were written out of the story of the development of the steam engine. When Watt died the workshop at his house in Heathfield, Birmingham, was left untouched until the 1860s and preserved exactly as it was when he left it.

In 1924, the house was demolished and it was [offered to] the Science Museum. We have an entire room with 6,500 objects in it. You're standing on the original floorboards, looking through the original window, opening the original drawers… It's like a proto-shed because, as nowadays, people have stuff in sheds that sits gathering dust, which is exactly what Watt did, except the projects he was working on provide an outstanding physical record of his work. He could've had an equally successful career as a potter, chemist or surveyor as steam engineer. So Watt was a very multi-talented bloke.



The Newcomen engine could replace 120 horses turning chain pumps, or the equivalent of about 2,000 men with buckets doing the same work

1807
The first proficient commercial steam boat is launched – Robert Fulton's North River Steamboat.

1812
The first commercial locomotive is constructed by Matthew Murray. Eight years later there are 20 steam locomotives in service.

1827
Goldsworthy Gurney builds a steam carriage to be used as a vehicle on the roads, motoring along at 15mph.

1884
The steam turbine replaces steam power in its previous form with Charles Parson's axial-flow turbine.

1918
The end of the longest working atmospheric engine. Built by Francis Thompson in 1791, it stood at Pentrich Colliery.

© Science Museum

WHAT WAS THE NEWCOMEN STEAM ENGINE?

How did this groundbreaking engine work and how did it help bring about the Industrial Revolution?

The Newcomen steam engine – which was named after its inventor Thomas Newcomen – was the world's first practical device designed to harness the power of steam for mechanical work. The first one was built in 1712.

The machine worked by combining the pre-existing technologies of a steam cylinder with a steam-driven piston to raise and lower a pump rod via a balance beam (for a complete mechanical breakdown of the process see the central diagram). The result of this combination enabled Newcomen to create a lifting engine that by simply burning coal could continuously pump large quantities of water out of wells, mines and other reservoirs without the need of manual labour (pumps were usually driven by horse prior to this invention).

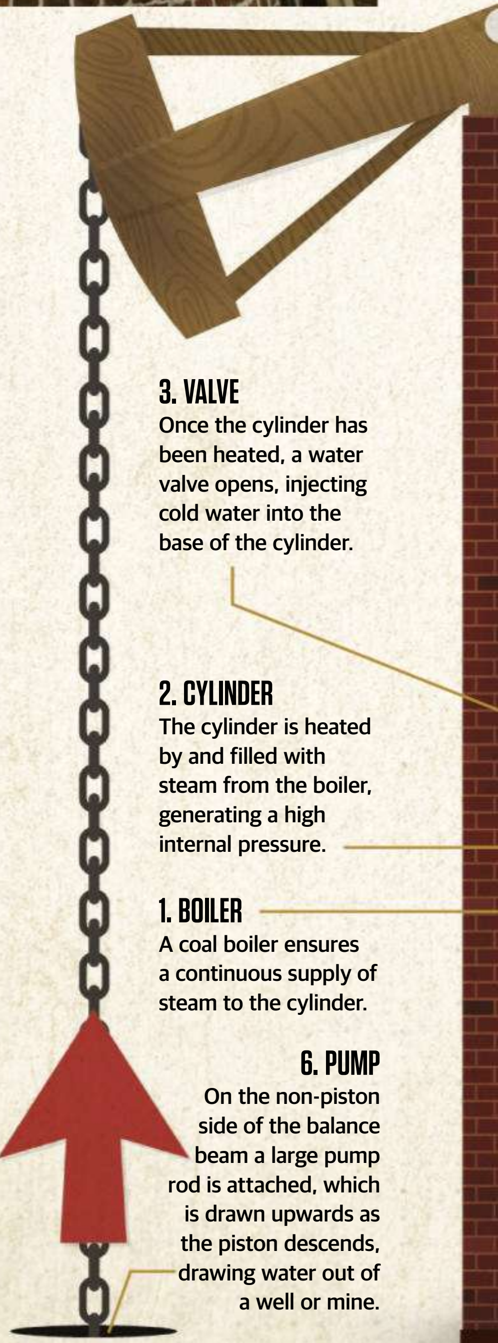
Indeed, the relative simplicity of the device and cost-effectiveness when compared to maintaining a stable of animals, in combination with the rapid expansion of England's industry in the early 18th century, saw the machine surge in popularity, with Newcomen engines installed not just in England, Scotland and Wales but also on mainland Europe. In fact, by the mid-18th century – only 40 or so years after Newcomen invented his engine – there were more than 100 systems in operation. For this reason, and in light of the massive role that the steam engine would play in developing swathes of British industry, today Newcomen's game-changing invention is rightly seen as one of the primary catalysts of the Industrial Revolution.

Not surprisingly, however, Newcomen's engine was incredibly crude by modern standards, and indeed those reached by the latter end of the 18th century. In fact it suffered from a fundamental flaw that was only addressed in 1769. This was that by directly cooling the engine's piston cylinder for each steam cycle, much of the boiler's generated steam was wasted bringing it back up to temperature in the next. This problem was exacerbated by the fact that the larger the Newcomen engine, the larger the cylinder, and, as a direct consequence, the more steam was needed to reheat the cylinder. This led to ever-greater quantities of steam to be wasted in the heat-up process and so ever-more coal was burnt to facilitate this.

Regardless of this flaw, the Newcomen engine's ability to transform the power of steam into kinetic energy and mechanical work was a huge milestone in human engineering that played a key role in shaping British industry at this pivotal point in the country's history.

▲ The only working Newcomen engine in the world is at the Black Country Living Museum, UK. This is the steam boiler part of the engine

◄ This is a model of a Newcomen engine built at Griff Colliery in Nuneaton, Warwickshire, in 1720



3. VALVE
Once the cylinder has been heated, a water valve opens, injecting cold water into the base of the cylinder.

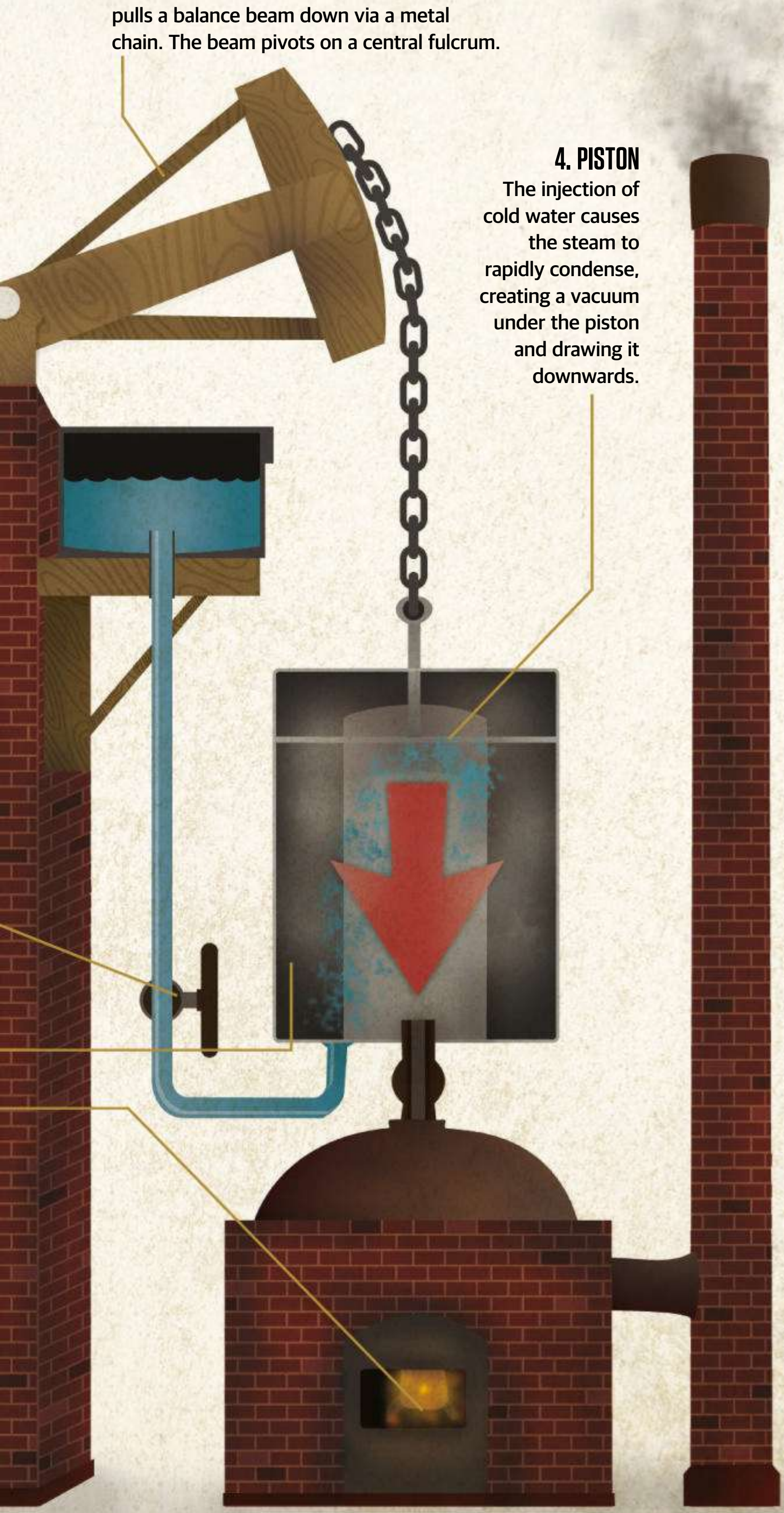
2. CYLINDER
The cylinder is heated by and filled with steam from the boiler, generating a high internal pressure.

1. BOILER
A coal boiler ensures a continuous supply of steam to the cylinder.

6. PUMP
On the non-piston side of the balance beam a large pump rod is attached, which is drawn upwards as the piston descends, drawing water out of a well or mine.

HOW DID THE NEWCOMEN ENGINE GENERATE POWER?

Follow our step-by-step guide to the workings of this revolutionary piece of machinery



5. BEAM

The downward movement of the piston pulls a balance beam down via a metal chain. The beam pivots on a central fulcrum.

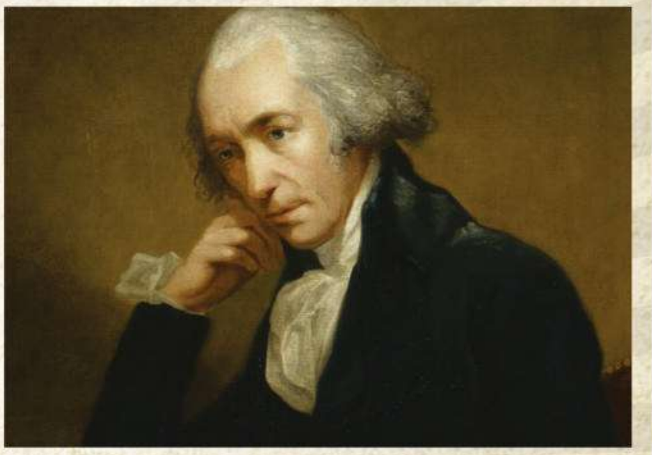
4. PISTON

The injection of cold water causes the steam to rapidly condense, creating a vacuum under the piston and drawing it downwards.

WHAT DID WATT DO?

Today, James Watt is known as the father of the steam engine, but does he deserve all the credit?

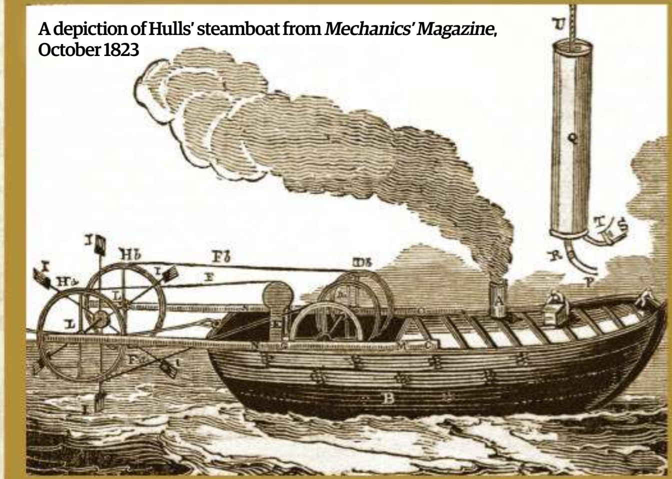
As mentioned, the main problem with Newcomen's steam engine was that it was incredibly costly to operate. This was because each time its central cylinder was cooled to create a vacuum, the cylinder walls remained cold as the next wave of steam was fed in, condensing a proportion of it immediately. This reheating of the cylinder wasted a large quantity of steam, dramatically increasing coal consumption. This problem was solved in 1769 by Scottish engineer James Watt, who realised while repairing an old Newcomen engine at Glasgow University that if condensation took place in a separate container attached to the steam cylinder by pipe the latter could remain hot at all times. Watt proceeded to patent his new steam engine and, despite it being heavily based on Thomas Newcomen's original, avoided paying any royalties by rigorously defending a number of lawsuits personally.



HULLS' NEWCOMEN STEAMBOAT

Although never made, this was one of the first attempts to create a steam-powered vessel

Since their inception, steam engines were increasingly seen as a future means of vehicle propulsion. A good example can be seen in English inventor Jonathan Hulls' design of a steamboat (below), a small vessel powered by a Newcomen engine. Unfortunately, despite being granted a patent for his steamboat in 1736, it was never built as the inefficient and cumbersome engine was thought unfeasible. Interestingly, it wasn't until 1774 that a working steamboat was successfully piloted, with Claude-François-Dorothée, Marquis de Jouffroy d'Abbans, building and captaining the *Palmipède* ('web-toed') vessel in Lyon, France.



A depiction of Hulls' steamboat from *Mechanics' Magazine*, October 1823

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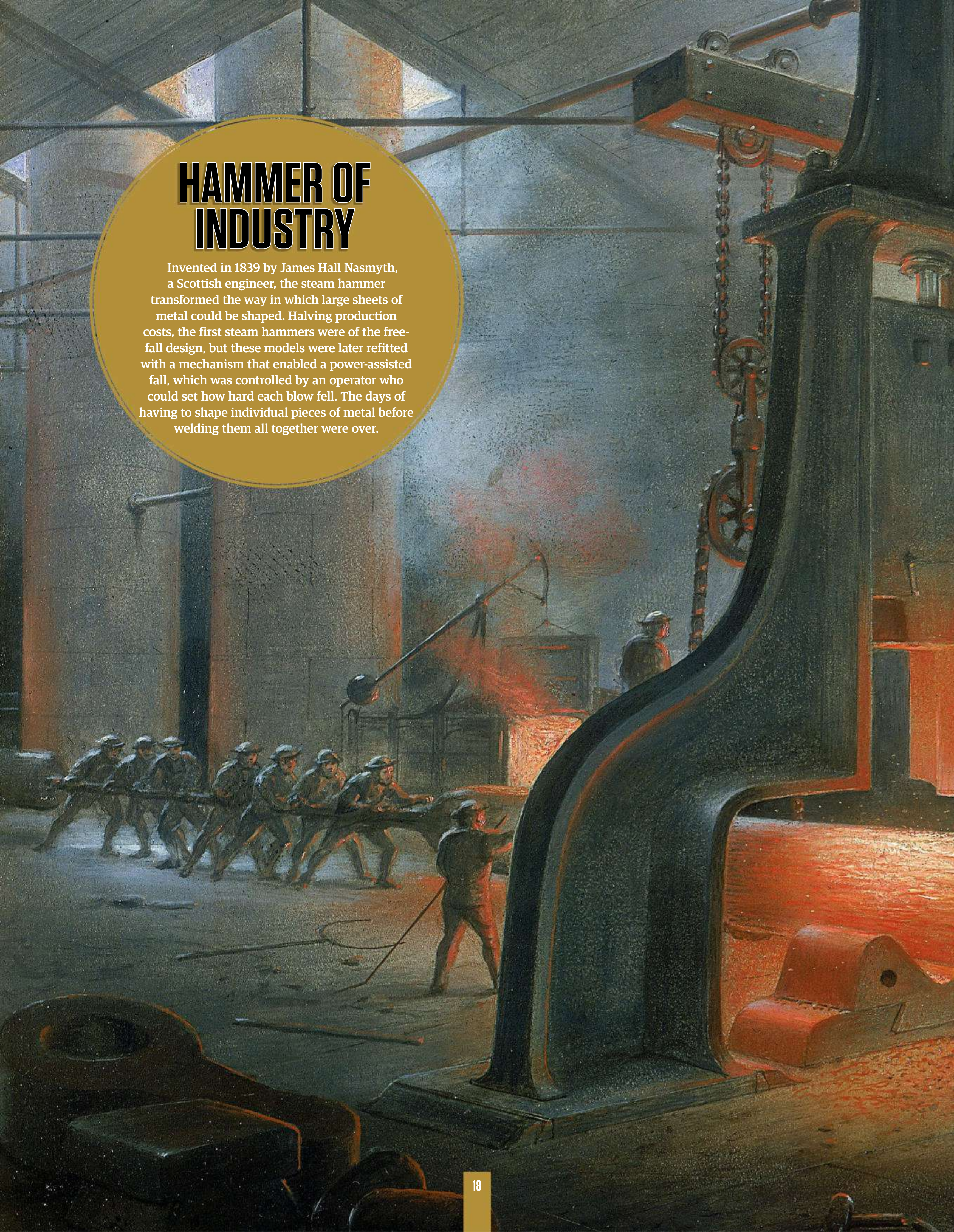
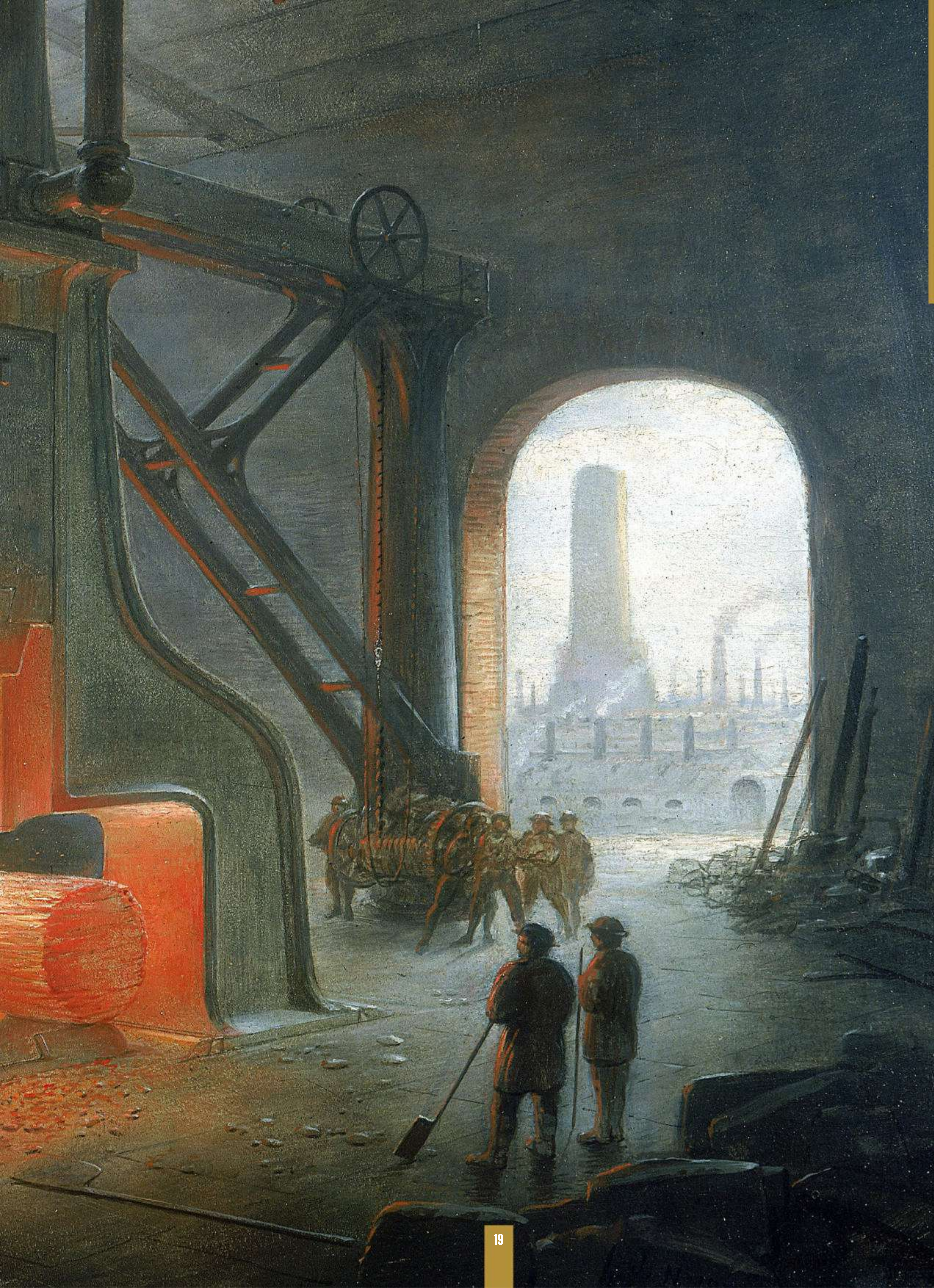


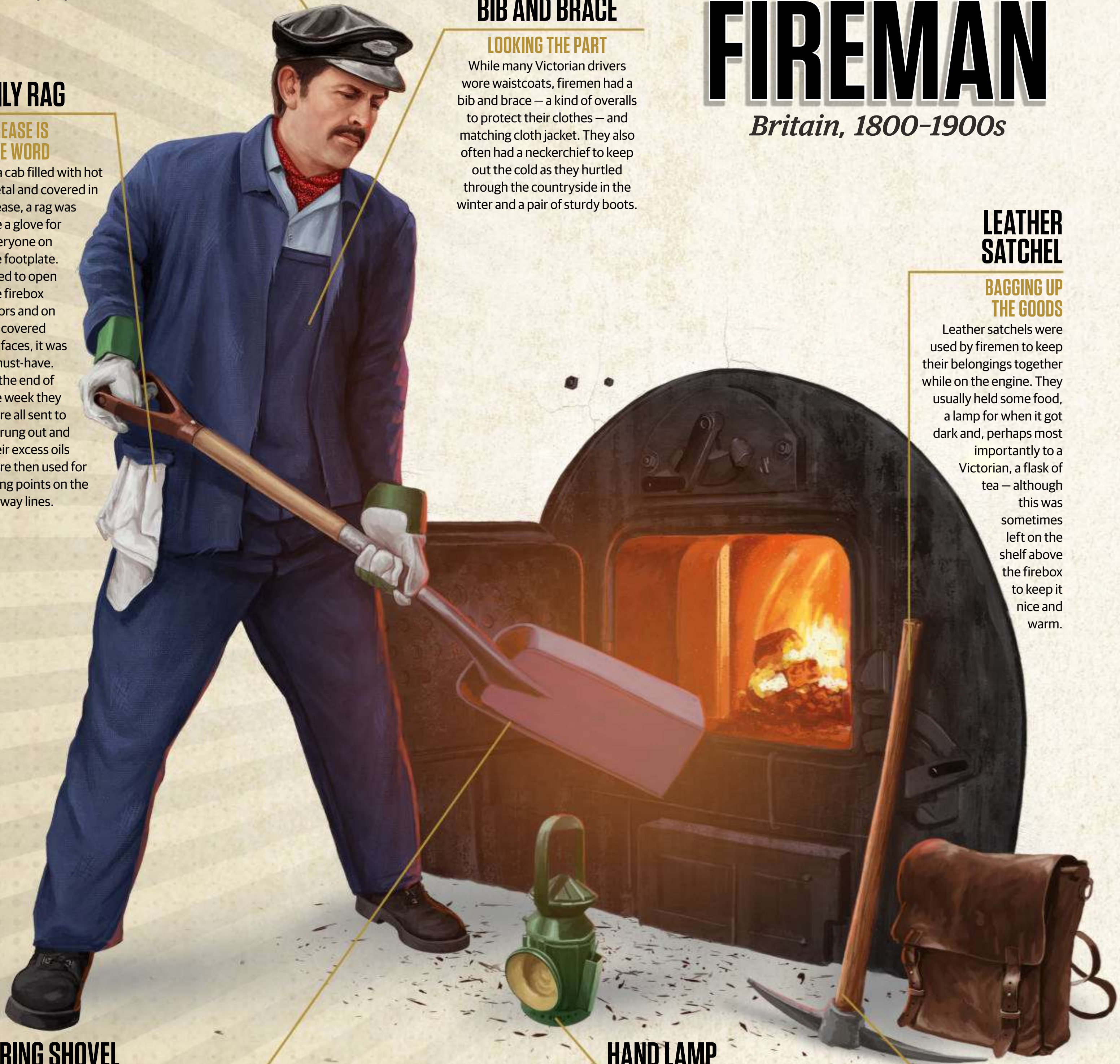
HAMMER OF INDUSTRY

Invented in 1839 by James Hall Nasmyth, a Scottish engineer, the steam hammer transformed the way in which large sheets of metal could be shaped. Halving production costs, the first steam hammers were of the free-fall design, but these models were later refitted with a mechanism that enabled a power-assisted fall, which was controlled by an operator who could set how hard each blow fell. The days of having to shape individual pieces of metal before welding them all together were over.



ANATOMY OF A RAILWAY FIREMAN

Britain, 1800–1900s



GREASE TOP HAT

HEADS UP!

It was rare to find a fireman without a hat. More than a means to keep coal smut out of their hair, it provided some protection if they hit their head on the cab's low metal ceiling. The hat might also sport a badge advertising the railway they worked for.

OILY RAG

GREASE IS THE WORD

In a cab filled with hot metal and covered in grease, a rag was like a glove for everyone on the footplate. Used to open the firebox doors and on oil-covered surfaces, it was a must-have. At the end of the week they were all sent to be rung out and their excess oils were then used for oiling points on the railway lines.

BIB AND BRACE

LOOKING THE PART

While many Victorian drivers wore waistcoats, firemen had a bib and brace – a kind of overalls to protect their clothes – and matching cloth jacket. They also often had a neckerchief to keep out the cold as they hurtled through the countryside in the winter and a pair of sturdy boots.

LEATHER SATCHEL

BAGGING UP THE GOODS

Leather satchels were used by firemen to keep their belongings together while on the engine. They usually held some food, a lamp for when it got dark and, perhaps most importantly to a Victorian, a flask of tea – although this was sometimes left on the shelf above the firebox to keep it nice and warm.

FIRING SHOVEL

TOOL OF THE TRADE

A fireman's most important tool, a shovel with a sturdy handle was used to get the coal into the far reaches of the firebox. A delicate balance had to be achieved with the coal – too little and not enough pressure was created, but too much and there wouldn't be enough air for the coal to burn. Some firemen also had a slightly more unorthodox use for the shovel – frying up eggs and bacon on the hot (and filthy) metal.

HAND LAMP

LIGHTING THE WAY

Lanterns were carried by most members of staff on the railways while working at night. They usually ran off lamp oil and had different-coloured glass lenses – red, green and orange – to send signals to signalmen and crossing keepers.

COAL PICK

BREAKING UP THE FUEL

Just in case the lumps of coal were too big or got stuck together, a fireman always had a handy coal pick. To use it, he'd climb into the fuel bunker and swing it like a pickaxe to make sure that the coal was all the right size for the firebox.

© Kevin McGivern

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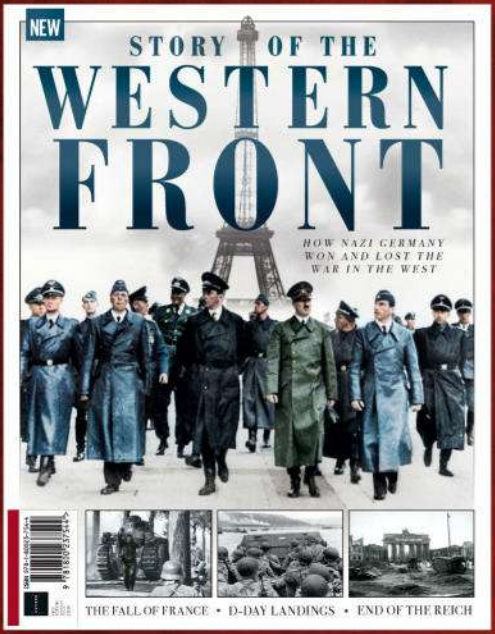
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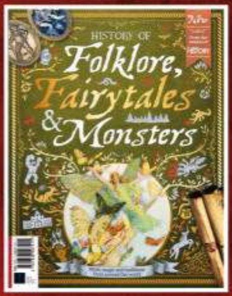
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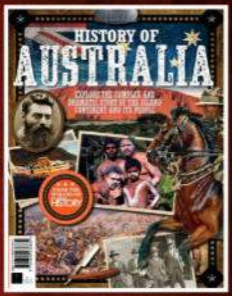
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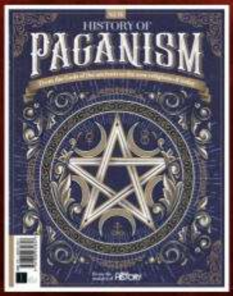
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RISE OF THE MACHINES

HOW THE STEAM AGE CHANGED THE WORLD

One of the most important periods in modern history, the Industrial Revolution generated materials, machines, tools, vehicles and technologies that completely transformed life on Earth...

The Industrial Revolution might have ended well over a century ago, but it's still relevant today as it embodies many of humanity's greatest characteristics. Traits that in a world of rapidly dwindling fossil fuels, fragile national economies and ever-increasing populations are going to be crucial in tackling the problems that lie ahead. Ingenuity, tenacity and scientific knowledge drove the Industrial Revolution and created a better world for the billions of people alive today. That noble ability to enrich the lives of future generations is something worth celebrating.

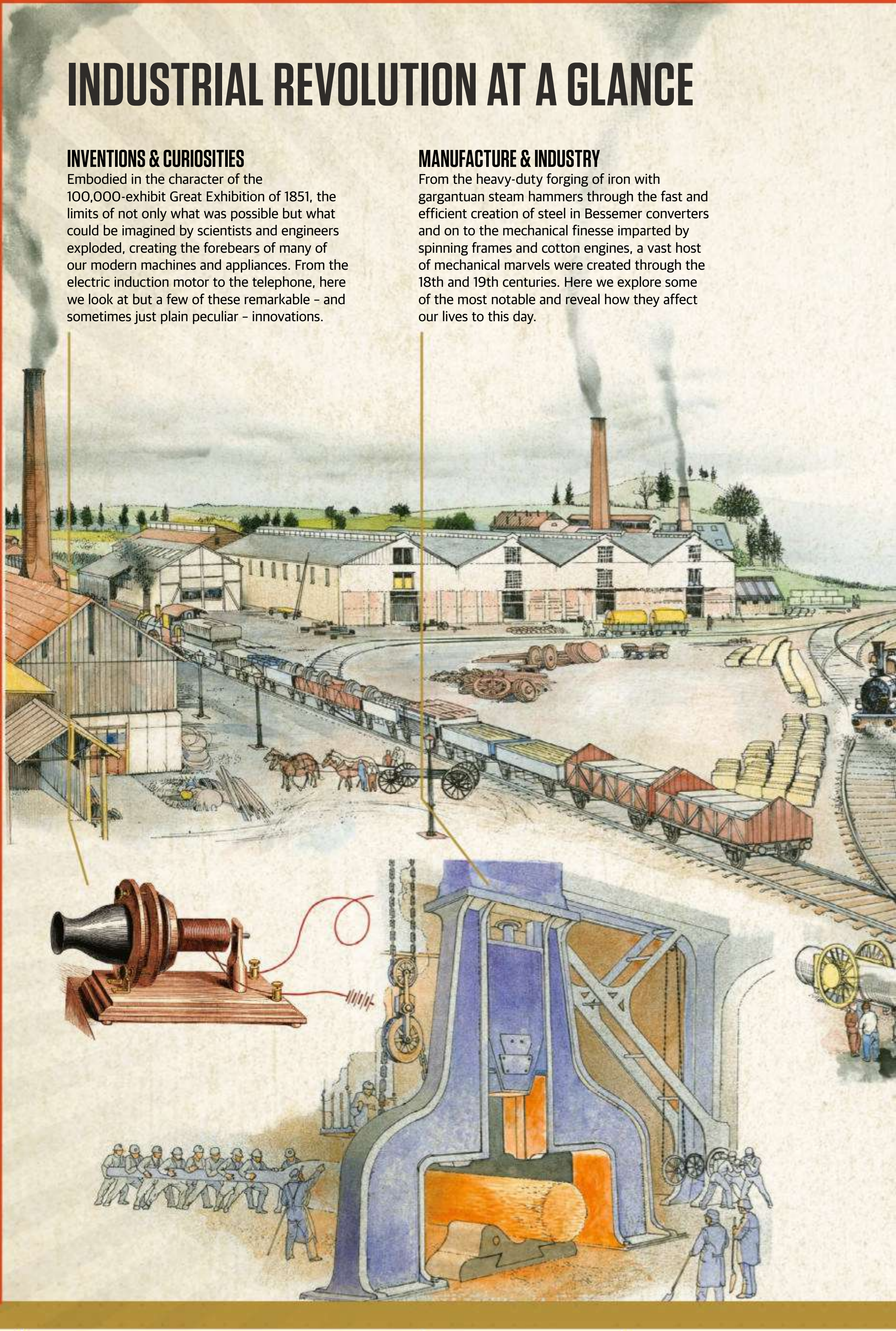
THE STEAM AGE

It's a common misconception that steam is visible. The characteristic white mist that we see rising from a boiling kettle or the cooling tower of a power station is, in fact, haphazard clouds of water droplets forming through the condensation of steam in the cooler air. Indeed, if steam was simply a mist of water droplets and nothing more it wouldn't be anywhere near as exciting as we're about to reveal.

No, true steam - generated when water molecules receive an energy excess great enough to break down their bonds - is of interest due to the massive growth in volume brought about by its phase change. This expansion clocks in at 1,700 times the volume of its liquid state (water) - a factor of 30,600:18. As such, a single mole of water (a mole of a substance is the mass of the material in grams that is numerically equal to its molecular mass) is 18 grams. However, at standard temperature and pressure that mole expands to fill a volume of 22.4 litres (39.4 pints) when vaporised. Conversely, the same factor is attributable to the reversed state change (i.e. condensation).

This process is far from merely a scientific curiosity. It is fundamental to understanding how arguably the biggest social, industrial and economic upheaval the world has ever witnessed unfolded over a period of 200 years. That upheaval

INDUSTRIAL REVOLUTION AT A GLANCE



INVENTIONS & CURIOSITIES

Embodied in the character of the 100,000-exhibit Great Exhibition of 1851, the limits of not only what was possible but what could be imagined by scientists and engineers exploded, creating the forebears of many of our modern machines and appliances. From the electric induction motor to the telephone, here we look at but a few of these remarkable – and sometimes just plain peculiar – innovations.

MANUFACTURE & INDUSTRY

From the heavy-duty forging of iron with gargantuan steam hammers through the fast and efficient creation of steel in Bessemer converters and on to the mechanical finesse imparted by spinning frames and cotton engines, a vast host of mechanical marvels were created through the 18th and 19th centuries. Here we explore some of the most notable and reveal how they affect our lives to this day.

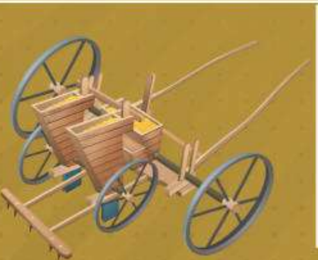
KEY DATES OF THE STEAM AGE

Chart some of the most game-changing inventions, developments and discoveries over 200 years

1701

Tull's seed drill

Jethro Tull's seed drill embodies the shift from an agrarian economy to one dominated by urban industry and machine manufacture.



1712

Newcomen engine

Thomas Newcomen's engine is an early glimpse into the possibilities of steam power. It's used mainly to drain mines of water but will later be adapted to do much more.

1733

Flying shuttle

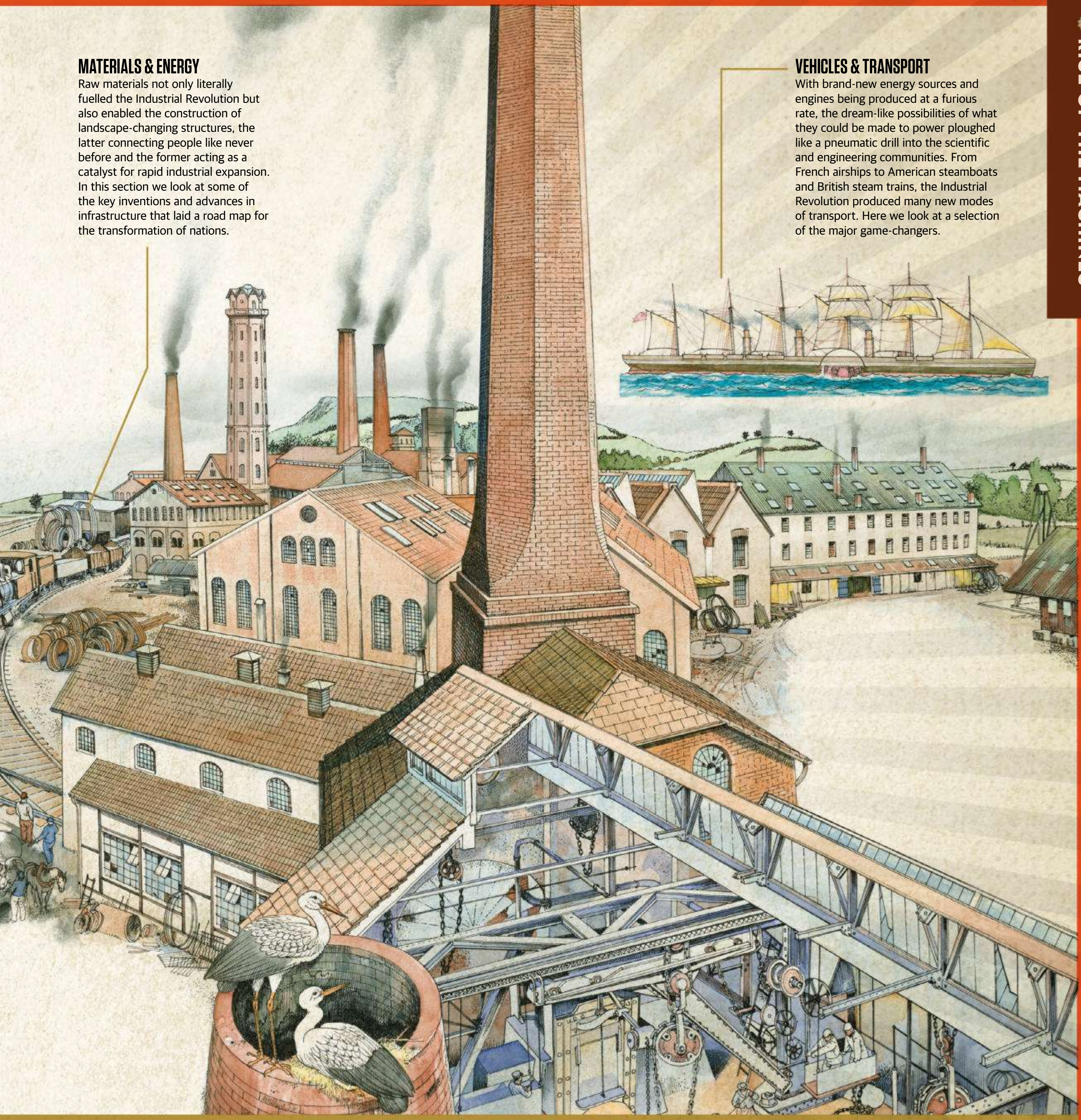
The invention of the flying shuttle in the mid-18th century allows for the larger-scale weaving of fabrics. It is eventually automated in machine looms.

MATERIALS & ENERGY

Raw materials not only literally fuelled the Industrial Revolution but also enabled the construction of landscape-changing structures, the latter connecting people like never before and the former acting as a catalyst for rapid industrial expansion. In this section we look at some of the key inventions and advances in infrastructure that laid a road map for the transformation of nations.

VEHICLES & TRANSPORT

With brand-new energy sources and engines being produced at a furious rate, the dream-like possibilities of what they could be made to power ploughed like a pneumatic drill into the scientific and engineering communities. From French airships to American steamboats and British steam trains, the Industrial Revolution produced many new modes of transport. Here we look at a selection of the major game-changers.



1764

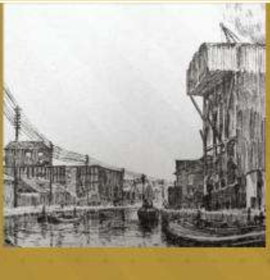
Spinning jenny

This spinning machine reduces the amount of work needed to produce yarn, allowing for multiple spools to be created at once, increasing efficiency.

1772

Bridgewater Canal

The successful completion of the Bridgewater Canal in northwest England kick-starts the rapid expansion of a vast canal network throughout Britain.



1775

Watt steam engine

James Watt's engine markedly improves on Newcomen's design from 60 years earlier, using steam at a pressure just above atmospheric to drive a piston.

was the Industrial Revolution, and that simple, invisible, beautiful expansion of volume was the driving factor of the steam engine - the machine that essentially built the modern world.

INDUSTRIES TRANSFORMED

The invention of the steam engine and its practical implementation in the beam engines of the early 18th century was the catalyst. By mechanising and automating the excavation of mines, not only could raw materials - such as coal and ores - be harvested in immense quantities, but the process could be executed at a speed simply infeasible for manual labourers. Soon, the rapidly increasing availability of coal and raw building materials allowed ever-more complex machines to be invented, housed in greatly upscaled industrial buildings like factories.

Everything was affected. From agriculture through to metal working, construction and the textile industry, the fuel surplus enabled more and more steam engines to be built, which in turn allowed more and more machines and processes to be automated. Workers who had until then found themselves confined to their area of birth were released from this geo-economic prison by roads and bridges and the quicker and cheaper transport they offered.

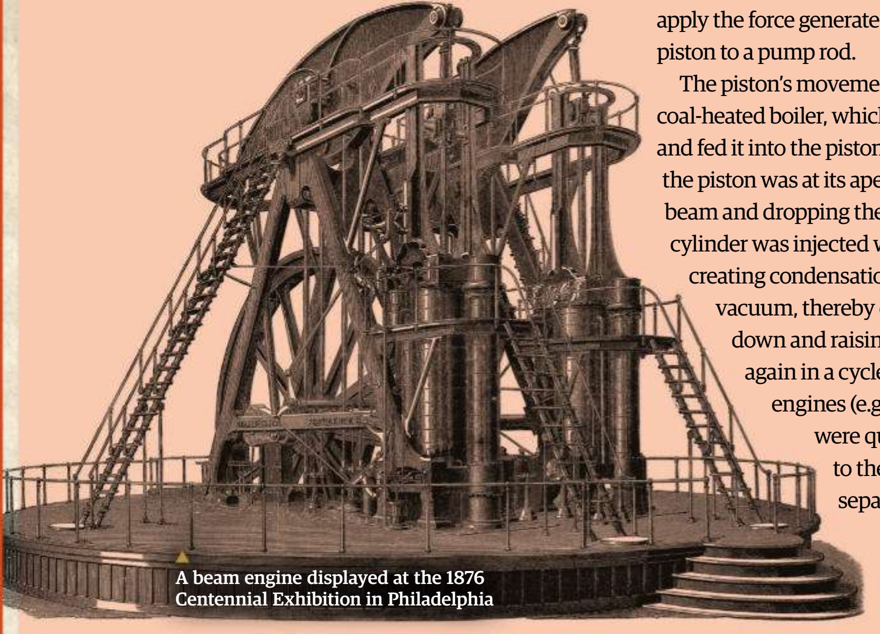
This expansion - not just industrially but socially and commercially - essentially led to the collapse of the existing social structure, with a wider distribution of wealth generating extra tiers within a nation's class system. It also led to the creation of modern industrial cities, with many industries increasingly bound by a mutual reliance on each other's trade and, importantly, the machines and power source (steam produced by coal) that, year by year, was becoming the norm.

RISE OF THE MACHINES

The Industrial Revolution saw machines put centre stage due to their ability to

1712 THE BEAM ENGINE

This invention allowed mines to be cleared of water mechanically so coal and ores could be excavated quicker than ever before



A beam engine displayed at the 1876 Centennial Exhibition in Philadelphia

The beam engine was used to draw out water from mines as well as to pump water into canals. The engine consisted of a large wooden frame to which was attached a pivoted overhead beam that was used to apply the force generated by a vertical piston to a pump rod.

The piston's movement was driven by a coal-heated boiler, which generated steam and fed it into the piston's cylinder. When the piston was at its apex - moving the beam and dropping the pump rod - the cylinder was injected with cold water, creating condensation and eventually a vacuum, thereby drawing the piston down and raising the pump rod again in a cycle. Early beam engines (e.g. Newcomen's) were quite inefficient due to their lack of a separate condenser.

KEY PLAYERS

ISAMBARD KINGDOM BRUNEL

Nationality: English

Role: Structural engineer

Born: 1806

Died: 1859

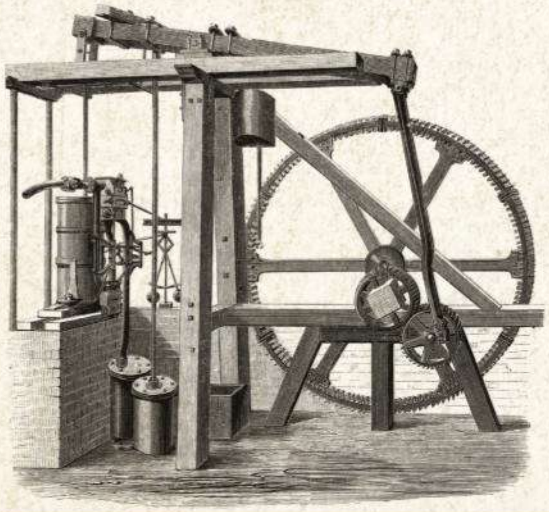
Known for: Thames Tunnel, Clifton Suspension Bridge, Great Western Railway

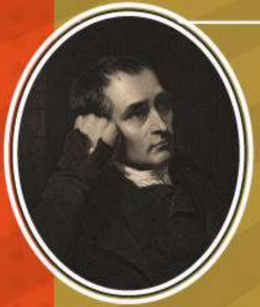
Responsible for the creation of bridges, tunnels, dockyards, railways and steamships, Brunel was one of the foremost mechanical and civil engineers of the era. Historical accounts frequently cite his remarkable ability to think up innovative solutions to both structural and mechanical problems.

1775 WATT'S STEAM ENGINE

James Watt brought steam to the masses, empowering industries to upscale and automate their operations

The Watt steam engine made two critical improvements to existing models. The first was the addition of a separate condenser cylinder alongside the main piston cylinder. This meant that the majority of condensation - and therefore vacuum creation - took place outside the heated drum. This allowed the main piston cylinder to remain at a temperature where water could quickly be pressurised. The second improvement was the introduction of an extra steam valve. The added valve increased the power of the engine as it capped and inserted low-pressure steam into the upper part of the main piston cylinder. This sped up vacuum creation, increasing the piston's downstroke power and, as a result, its actions per minute.





1779

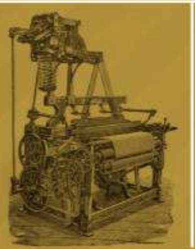
Spinning mule

English inventor Samuel Crompton's mule combines the spinning jenny and the water frame to fully automate the weaving process for the first time, ushering in a new era for the textiles industry.

1785

Power loom

Edmund Cartwright refines his power loom, a mechanised device powered by a line shaft that rapidly increases the speed of operation.



1793

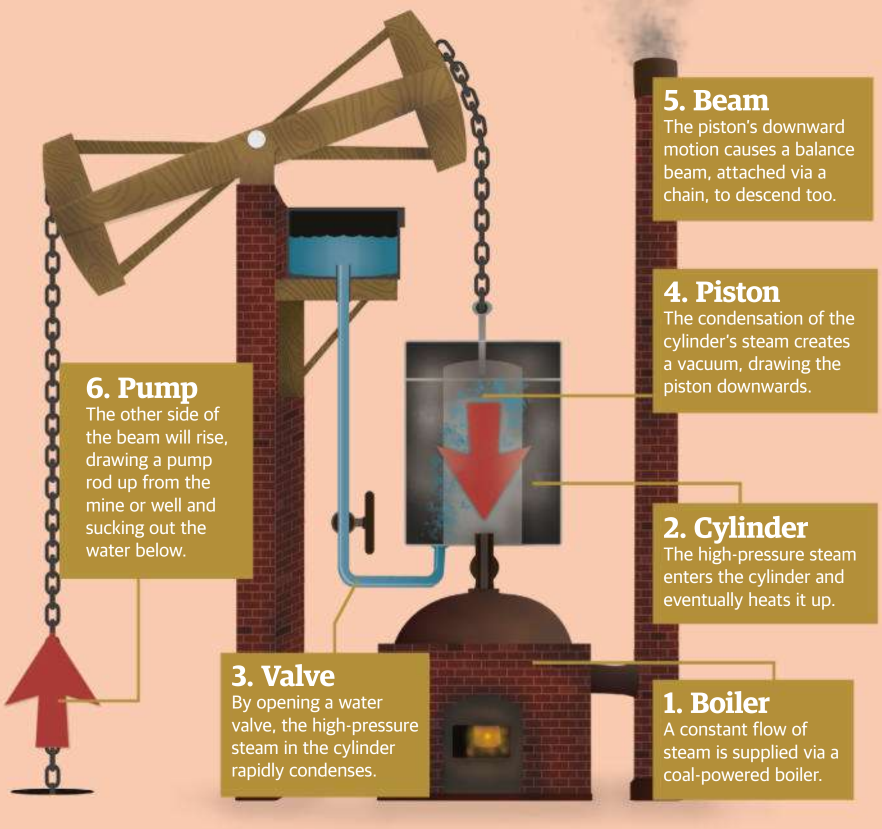
Cotton gin

American Eli Whitney invents the cotton engine, a machine that quickly separates cotton seeds from their fibres.

1801

Puffing Devil

British engineer Richard Trevithick demonstrates a steam-powered car – the Puffing Devil – and drives it up Camborne Hill, Cornwall. It can only travel short distances though.



1. Boiler
A constant flow of steam is supplied via a coal-powered boiler.

2. Cylinder
The high-pressure steam enters the cylinder and eventually heats it up.

3. Valve
By opening a water valve, the high-pressure steam in the cylinder rapidly condenses.

4. Piston
The condensation of the cylinder's steam creates a vacuum, drawing the piston downwards.

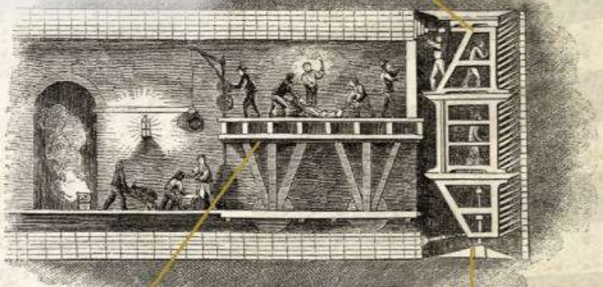
5. Beam
The piston's downward motion causes a balance beam, attached via a chain, to descend too.

6. Pump
The other side of the beam will rise, drawing a pump rod up from the mine or well and sucking out the water below.

1843 THE THAMES TUNNEL

The first tunnel to be built under a navigable river, this was one of Brunel's engineering milestones

The Thames Tunnel introduced the tunnelling shield. This consisted of three iron frames mounted on top of one another like an open-backed bookcase. This structure was placed against the area of earth that needed to be excavated and then workers proceeded to dig in its cavities, removing soil in sections. Once the distance of the cavities had been excavated it was shunted forward by a series of screw braces. This meant that at each stage of the dig the shield supported the walls and ceiling, allowing time for masonry reinforcements to be installed as the work progressed.



SHIELD
Essentially an iron scaffold structure, it shunts forward as excavations progress and supports the walls/ceiling.

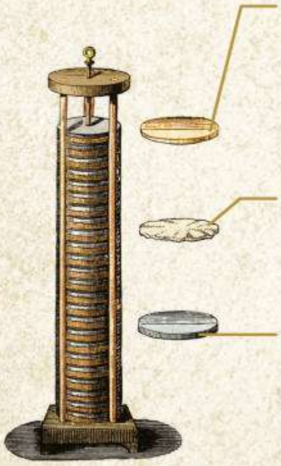
GANTRY
A wheeled wooden gantry acts as a platform for workers to stand on to reach the tunnel roof. It follows in the path of the shield.

BRACE
The shield and its cells are moved by screw braces that can be released when the tunnel has been reinforced with bricks.

1800 THE VOLTAIC PILE

The world's first electric battery, made by Alessandro Volta, led to a boom in electrochemical power supplies and the discovery of electrolysis

The voltaic pile was a set of individual electrochemical cells placed in a stack separated by an electrolyte, such as pasteboard soaked in brine. When both ends of the tower were connected with wire, it generated an electric current. The pile produced a charge due to molecular reactions involving each zinc disc being partially dissolved by the acidic brine disc, leading to zinc atoms losing two electrons each. The zinc atoms became ions, passing into the brine disc and coming into contact with a silver or copper disc on the other side, where their lost electrons were replaced. This generated excess electrons within the zinc disc that would travel through the cell and replace the electrons stolen by the zinc atoms from the silver disc. This continuous flow of electrons created a steady current, which had eluded scientists for years.



3. COPPER DISC
As the zinc ions reach the copper disc they steal electrons, becoming reduced. The zinc disc's remaining electrons then pass through the cells, thereby completing the circuit.

2. PASTEBOARD DISC
The zinc ions pass through the acidic pasteboard disc as it acts as a crude electrolyte.

1. ZINC DISC
The zinc disc's surface is slightly dissolved by the pasteboard disc's brine, causing zinc atoms to lose electrons and turn into ions.

1779 IRON BRIDGE

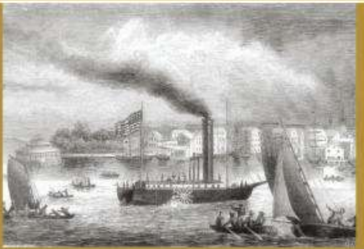
The first-ever arch bridge to be made purely from cast iron

The Iron Bridge in Shropshire consists of 482 main iron castings, which were forged at the Bedlam Furnaces 500 metres (1,640 feet) downstream and shipped by reinforced barges to the site. The construction of the huge iron components was made possible by improvements to furnace, moulding and pressing equipment, with many parts needing to be heavily bowed, such as the structure's five parallel arch frames. After a complex assembly process, the road surface was finished with clay and blast furnace slag.

1807

Clermont steamboat

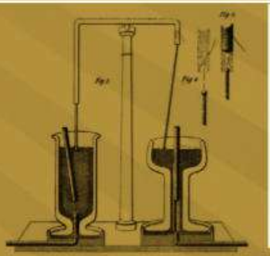
Following success with his Nautilus submarine, American engineer Robert Fulton sets up the world's first commercially successful steamship service with the Clermont steamship, operating around New York.



1821

Electromagnetic rotation

English scientist Michael Faraday demonstrates electromagnetic rotation – the principle of the electric motor. Ten years later he will discover electromagnetic induction.



1825

Thames Tunnel

Isambard Kingdom Brunel begins work on the first under-river tunnel ever to be attempted – the Thames Tunnel (see above for more details). It is completed in 1843.

perform tasks at a literally inhuman rate. Manual workers found they were no longer craftspeople but operators of steam hammers, water frames, power looms and more. They operated many of these steam-powered devices in factories - a new system of production also born in this period.

Prior to the 1700s the majority of industries were 'cottage industries', with small groups of craftspeople taking part in heavily localised operations producing limited goods. Taking the textiles industry as an example, wool and cotton fibres were spun by hand into yarn, then weavers turned them into bespoke items for a select few wealthy clients. However, with the advent of spinning frames and mechanised looms, these craftspeople were drawn together in a factory setting, where items could be created en masse. Due to the removal of hands-on skill in many of their roles, more untrained workers could be hired.

The scale of the integration of industrial machinery cannot be overstated. Every level of the textiles industry was transformed, with cotton engines allowing fibres to be separated from seeds rapidly, spinning frames enabling those fibres to be spun into yarn on a massive scale, and power looms driven by vast drive shafts allowing cloth to be weaved with unprecedented efficiency.

While the first half of the Industrial Revolution (circa 1750-1830) was characterised by stationary steam-powered machines, the second half (circa 1830-1900) saw an explosion in machines that moved. It was kick-started by Richard Trevithick's steam-powered locomotive and carriage, and then refined by a series of inventors who took mobile applications of the steam engine to another level. Soon steam-powered trains, carriages, balloons and ships were opening up the possibility of long-distance travel across the globe.

DRIVE TOWARDS GLOBAL TRAVEL

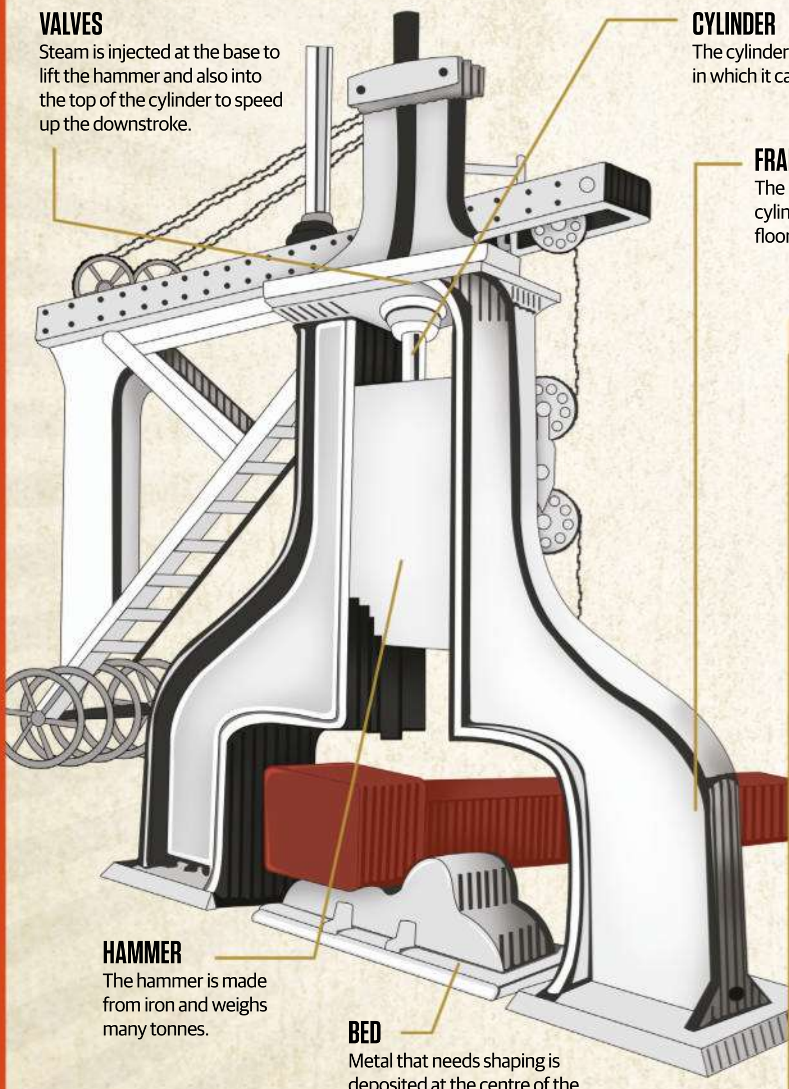
Beginning in Britain but soon spreading

1839 THE STEAM HAMMER

James Nasmyth's steam hammer took forging to a whole other level

The steam hammer was essentially a power hammer, as used today to shape forgings, but it was driven by a steam engine. It comprised a hammer-like piston within a cylinder positioned vertically in an iron frame. The central hammer piston was driven upwards by injecting high-pressure steam into the cylinder's base, which was supplied by an adjacent coal boiler. Once the hammer had been raised, the metal that needed forging was placed underneath on an iron bed. The steam at the bottom of the cylinder was then ejected rapidly via a condenser, creating a vacuum that, combined with gravity, caused the hammer to drop quickly onto the metal, shaping it as desired. Later, the drop speed of the hammer was further increased by injecting high-pressure steam into the top of the cylinder at the same time.

Despite its simple operation, the steam hammer gained huge traction in the metalworking industry, allowing machines to build other machines, structures and components at great speed. In addition, the technology also saw application in a range of other mechanised tools including the first automatic piledriver, a piece of engineering that reduced the time it took to install piles from hours to just minutes.



VALVES
Steam is injected at the base to lift the hammer and also into the top of the cylinder to speed up the downstroke.

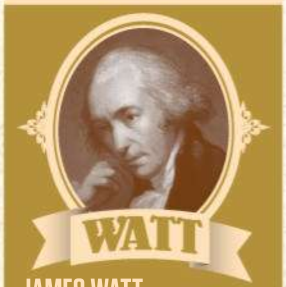
CYLINDER
The cylinder houses the hammer piston, in which it can rise and fall vertically.

FRAME
The hammer piston and cylinder are elevated off the floor via a large metal frame.

HAMMER
The hammer is made from iron and weighs many tonnes.

BED
Metal that needs shaping is deposited at the centre of the frame on an iron bed.

KEY PLAYERS



JAMES WATT

Nationality: Scottish

Role: Mechanical engineer

Born: 1736

Died: 1819

Known for: Watt steam engine, Soho Foundry, International System of Units (SI)

Watt's steam engine was a cornerstone of the Industrial Revolution, transforming the feasibility of employing steam as an energy source. The power gain – improved efficiency and low running costs – that Watt engines delivered allowed for rapid expansion in the mining, metalworking and fabric industries to name just a few.

1834

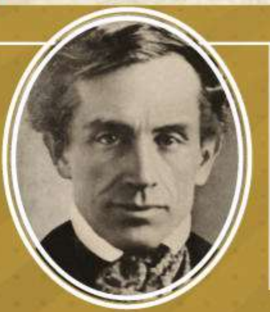
Analytical engine

The English inventor and mathematician Charles Babbage begins work on the analytical engine, which is a mechanical forerunner of the modern computer.

1837

Morse code

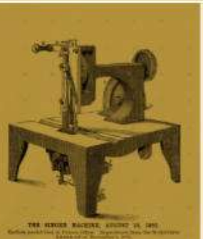
The electrical telegraph is improved by Samuel Morse (right). Morse code, however, is developed by his assistant Alfred Vail.



1851

Singer sewing machine

The first practical, mass-produced sewing machine is invented by the Singer Sewing Machine Company in New Jersey, U.S. It is still making machines to this day.



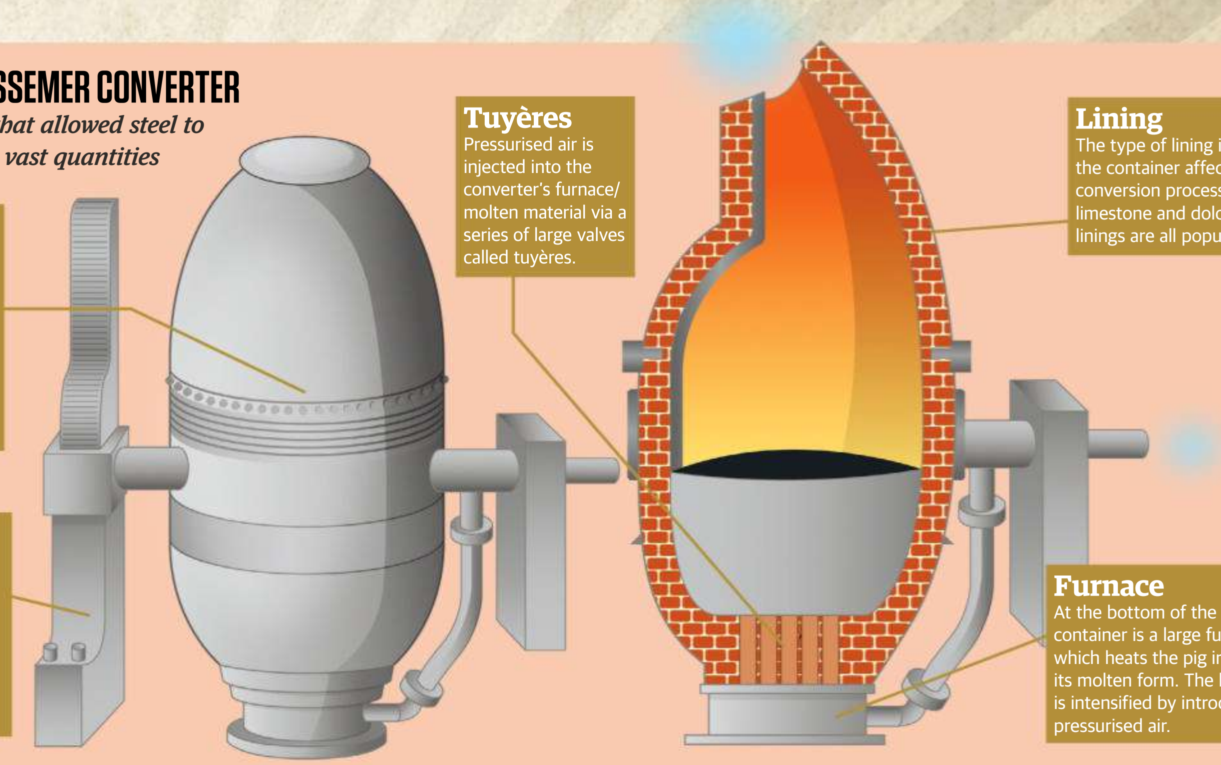
1856

Bessemer converter

Henry Bessemer invents the Bessemer converter, a process that enables the mass production of steel from pig iron, described in more depth opposite.

1856 THE BESSEMER CONVERTER

The invention that allowed steel to be produced in vast quantities



Container
The converter's container is roughly egg shaped and features a top-mounted opening for both inserting and extracting materials.

Struts
The container is elevated off the ground on a pair of large metal struts. This allows the container to be tilted to pour out molten steel.

Tuyères
Pressurised air is injected into the converter's furnace/molten material via a series of large valves called tuyères.

Lining
The type of lining in the container affects its conversion process. Clay, limestone and dolomite linings are all popular.

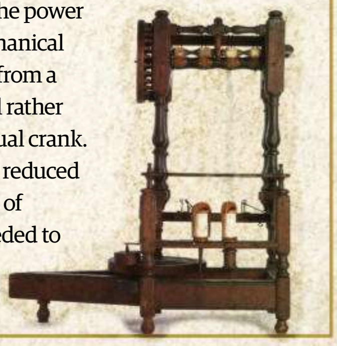
Furnace
At the bottom of the container is a large furnace, which heats the pig iron into its molten form. The heat is intensified by introducing pressurised air.

The Bessemer converter was a machine and surrounding process that involved the removal of impurities from pig iron (a type of iron with a high carbon content) and its conversion into steel, a material that had historically been costly and time consuming to manufacture. The key principle behind its operation was the removal of impurities such as silicon, manganese and carbon through oxidation, turning the brittle, largely unusable pig iron into very useful steel. The oxidation of impurities occurred in a Bessemer converter, a large egg-shaped container in which the iron was melted. The solid iron was inserted through a hole at the top and heated from the bottom. Once the converter had melted the pig iron, pressurised air was injected through and across the liquid metal, forcing the unwanted silicates to react with oxygen and convert into gas and/or solid oxides (i.e. slag). Once the oxidation process had taken place, the usable molten steel could be poured out from the container directly by tipping it on a central pivot (the container was suspended off the ground by a pair of large struts) while the slag could be skimmed off the surface for reuse or disposal. The steel was emptied into large moulds, where it could be set into a wide range of products.

1768 THE SPINNING FRAME

During the 18th century, spinning technology went through a great metamorphosis that would revolutionise the textiles industry

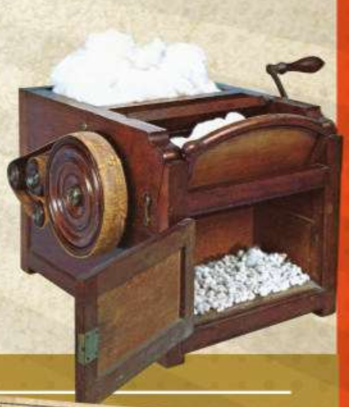
The spinning jenny, the original spinning frame made by James Hargreaves in 1764, worked by twisting bundles of fibres into thread and winding it onto spindles for looms. The jenny's mechanical action was generated by a hand crank, which was turned to produce the twisting motion. In 1768, Richard Arkwright's spinning frame hugely improved the speed at which thread could be produced. It was enhanced again by Arkwright's water frame. The latter worked largely the same way as the previous spinning frame, but the power for the mechanical parts came from a water wheel rather than a manual crank. This greatly reduced the number of workers needed to make thread.

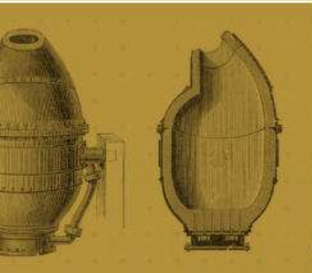


1793 THE COTTON GIN

Saving thousands of hours of manual labour, this machine turned the cotton industry on its head

The cotton gin – short for cotton engine – consisted of a small wooden box-frame in which a wooden cylinder was surrounded by a spiked metal mesh. On the outside of the frame, the cylinder was attached to a hand crank that, when rotated, would cause the cylinder to spin. The rotating motion picked up raw cotton balls from a hopper and pulled them through the metal mesh, drawing the cotton lint into thin fibres and collecting the seeds at the same time.





1864

Dynamite

Swede Alfred Nobel invents the explosive substance dynamite for use in mining.

1866

Transatlantic cable

After several failed attempts, the first permanent cable to cross the Atlantic Ocean is completed, speeding up communication between Britain and the U.S.

MAP OF THE SUBMARINE TELEGRAPH
BRITISH AMERICA
UNITED STATES
Printed for HOWE'S ADVENTURES & ACHIEVEMENTS OF AMERICANS

throughout Europe, America and many other parts of the world, these new mobile machines led to the creation of vast new transport networks. New roads were constructed to accommodate carriages; new railroads were laid to carry steam trains laden with food, coal and produce; new canals were excavated on a grand scale between major industrial cities; and new laws were passed to allow inventors to trial machines that could fly for miles in the skies or cruise silently beneath the ocean waves. These advances expanded the availability of labour, raw materials and products massively, and drew people together like never before.

Of course the age of steam and steam-powered inventions couldn't last for long in the enlightened environment it had inspired. The rise of science and engineering culturally, as well as the increasing knowledge of material science, led to the creation of new forms of energy and explosive new prime movers. The electric battery was invented and the electric motor was derived from it; before the close of the 19th century the internal combustion engine had fired up, driven by the development of petrol and diesel.

These new power sources took mechanical engineering to another level, allowing devices such as the incandescent lamp, phonograph, electrical telegraph, telephone, automobile and aeroplane to not just be invented but produced across the globe on a massive scale.

The expansion was unstoppable, and by the end of the 19th century most Western countries were all but unrecognisable from the nations they had been at the turn of the 18th. Cities were packed with machines, vehicles, businesses, people and, crucially – indeed, the greatest legacy of the entire movement – knowledge on a truly industrial scale. It was a newfound level of understanding that would see the world transform throughout the 20th century. So, you see, we weren't exaggerating when we said steam really is quite interesting…

1829 STEPHENSON'S ROCKET

Although not the first steam train to be built during the Industrial Revolution, Stephenson's Rocket incorporated lots of advanced technology into one vehicle

The father-and-son-made Stephenson's Rocket was such a success because it combined five key innovations. The first innovation was a single pair of driving wheels with a small carrying axle behind that allowed the weight of the coupling rods to be significantly reduced. In addition, as 2.3 tonnes of the Rocket's total 3.8-tonne weight was positioned over the forward driving wheels, the second axle could be smaller – again cutting weight. This reduction improved speed and efficiency, the latter bolstered by the Rocket's use of a multi-tube boiler array. By installing 25 copper fire tubes instead of a single large tube to carry exhaust gases from the firebox to the chimney, a much bigger area of hot piping was created and consequently more steam. The integration of a blastpipe aided the extra steam generated by feeding exhaust steam from the train's cylinders into a smokebox beneath its chimney; this boosted the intensity at which air was drawn through the system. This increase in raw steam power was bolstered by the separation of the enlarged copper firebox from the boiler. The final major innovation on the Rocket was the positioning of its two cylinders at a close to horizontal angle. By arranging the cylinders this way – with their pistons powering a pair of drive wheels – the train was able to eradicate an uneven swaying motion that had been a big problem on previous vehicles.

The statistics…

Stephenson's Rocket

Built: 1829

Wheel arrangement: 0-2-2

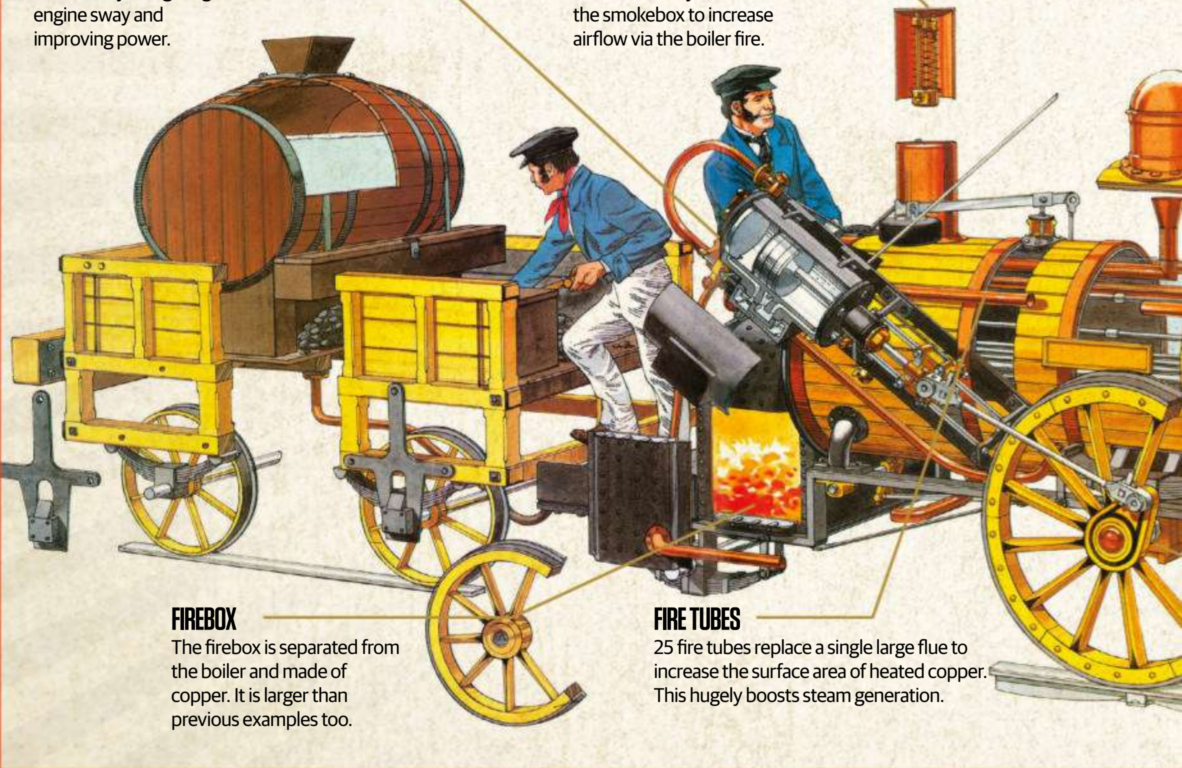
Weight: 3,800kg (8,377lb)

Fuel: Coke

Boiler pressure: 3.5kg/cm² (50psi)

Cylinders: 2

Top speed: 47kph (29mph)



CYLINDER
The Rocket's cylinders are mounted almost horizontally, mitigating engine sway and improving power.

BLASTPIPE
The blastpipe discharges exhaust steam from the Rocket's two cylinders into the smokebox to increase airflow via the boiler fire.

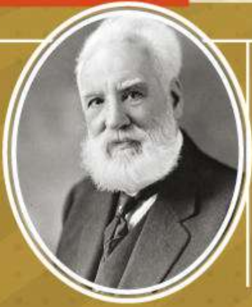
FIREBOX
The firebox is separated from the boiler and made of copper. It is larger than previous examples too.

FIRE TUBES
25 fire tubes replace a single large flue to increase the surface area of heated copper. This hugely boosts steam generation.

1876

Bell telephone

Scottish-born engineer Alexander Graham Bell invents the telephone, improving on a water transmitter system that was pioneered by American Elisha Gray.



1877

Edison phonograph

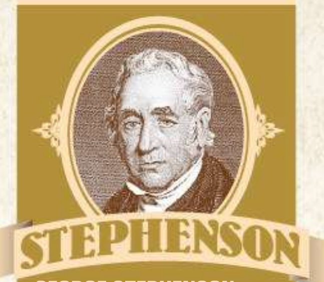
The world's first phonograph is invented by Thomas Edison, allowing for the recording and reproduction of audio for the first time.

1880

Incandescent lamp

Although there are a number of earlier attempts, Thomas Edison patents the first commercial incandescent lamp that will become the precursor to modern-day light bulbs.

KEY PLAYERS



GEORGE STEPHENSON

Nationality: English

Role: Civil engineer

Born: 1781

Died: 1848

Known for: Stephenson's Rocket, safety lamps

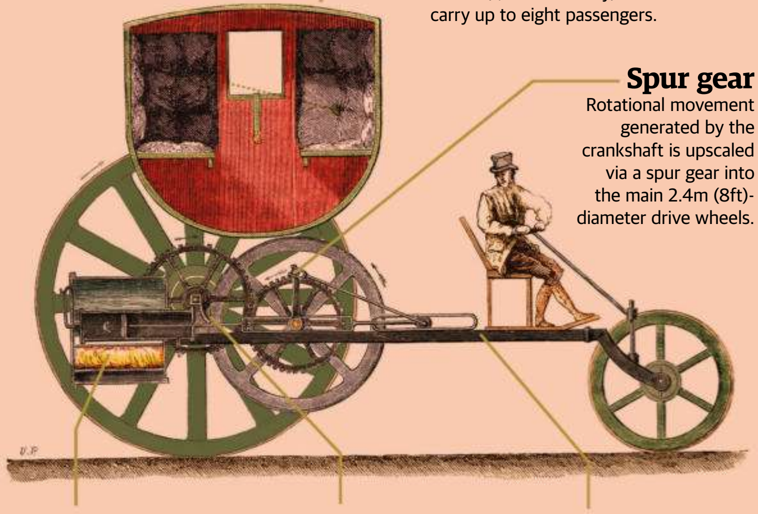
Engineer George Stephenson not only invented the world's first public railway line that used solely steam locomotives but also played the main role in making the Rocket steam train, miners' safety lamps and skew arch bridges. He is sometimes referred to as the 'Father of Railways'.

1803 THE LONDON STEAM CARRIAGE

The world's first self-propelled, passenger-carrying vehicle introduced the possibility of horseless travel

Replacing horses as a means of power required the carriage to be raised from its traditional position near the ground in order to accommodate the engine and gearing. The engine used high-pressure steam to drive a single cylinder and piston, which in turn powered a crankshaft. The linear motion produced by the piston was converted by the crankshaft into rotational motion and transferred into a spur gear, which turned the axle of the driving wheels. On top of this the crankshaft powered the engine's steam cocks, force pump and firebox bellows as well.

Unique to the design was the addition of a forked piston rod, which effectively closed the gap between the piston head and crankshaft. Another innovation was the use of a valve gear, allowing for the carriage's flywheel to be scaled down, improving efficiency and top speed.



Cabin
The seating area is created by traditional coachbuilder William Felton and costs £207 (over £6,500/$10,500 today). It can carry up to eight passengers.

Spur gear
Rotational movement generated by the crankshaft is upscaled via a spur gear into the main 2.4m (8ft)-diameter drive wheels.

Boiler
The carriage's boiler, along with its firebox, is installed at the rear of the vehicle behind the driving axle. The boiler powers a single horizontal cylinder.

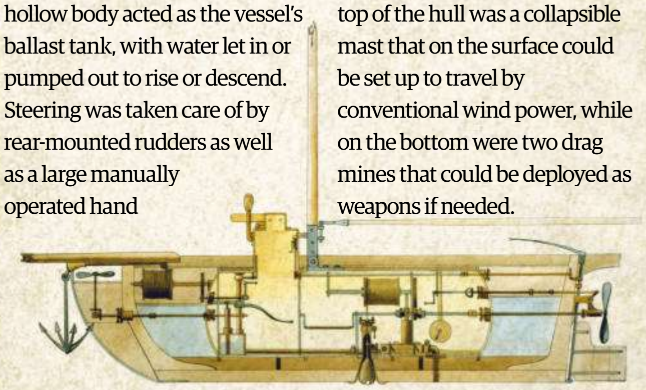
Piston rod
The piston connects to a forked piston rod, with the latter connecting to a crankshaft. The forked rod considerably reduces the distance between piston and crankshaft.

Crankshaft
The crankshaft converts the linear, reciprocating motion of the cylinder's piston into rotational movement, which in turn can be used to drive the carriage's gears.

1800 THE NAUTILUS SUBMARINE

The inspiration for Jules Verne's famous fictional sub, Robert Fulton's Nautilus was the first practical submarine to be built

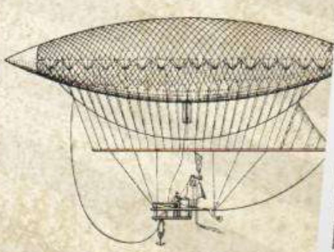
The Nautilus consisted of an ellipsoid tube of iron ribs covered by a series of riveted copper sheets and measured 6.5 metres (21.3 feet) in length. The hollow body acted as the vessel's ballast tank, with water let in or pumped out to rise or descend. Steering was taken care of by rear-mounted rudders as well as a large manually operated hand crank. This crank was directly connected to an external screw propeller, which gave a top speed of 3.2-4.8 kilometres (two to three miles) per hour. On the top of the hull was a collapsible mast that on the surface could be set up to travel by conventional wind power, while on the bottom were two drag mines that could be deployed as weapons if needed.

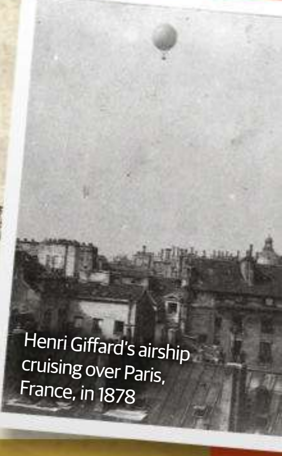


1852 THE GIFFARD DIRIGIBLE

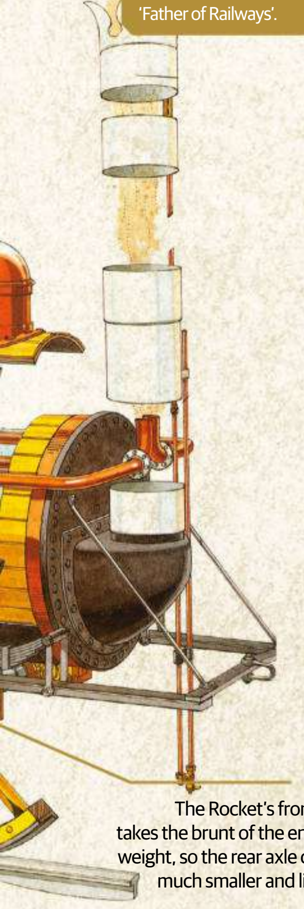
Discover the first-ever airship to be powered by a steam engine

The 1852 Giffard dirigible consisted of a 44-metre (144-foot)-long hydrogen balloon that was encircled by a rope matrix. From the matrix hung a single metal pole that supported a gondola. The gondola was installed with a steam engine capable of producing just 2.2 kilowatts (three horsepower) that could turn the dirigible's large, gondola-mounted propeller at approximately 110 revolutions per minute.





Henri Giffard's airship cruising over Paris, France, in 1878



AXLE
The Rocket's front axle takes the brunt of the engine's weight, so the rear axle can be much smaller and lighter.

1885

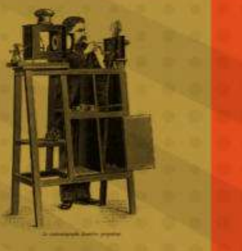
Benz Motorwagen
Karl Benz's Patent-Motorwagen is developed and becomes the world's first commercially sold, mass-produced car, 23 years before Henry Ford releases his Model T.

1892

Diesel engine
German engineer Rudolf Diesel invents the diesel engine, which centres around the principle of fuel compression.

1895

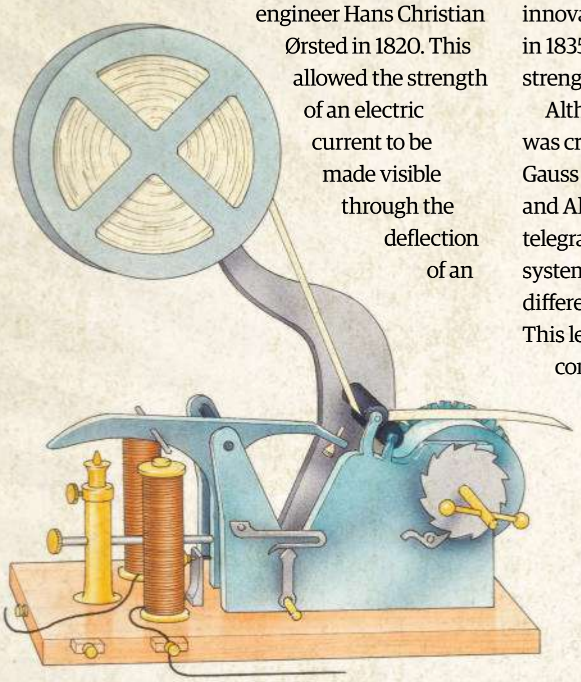
Lumière cinematograph
What will become the first practical and successful motion-picture film camera is created, kick-starting the cinema industry.



> **“MORSE AND VAIL CREATED MORSE CODE – A SYSTEM OF SENDING PULSES OF ELECTRICAL CURRENT AT DIFFERENT LENGTHS DOWN A NETWORK OF METAL CABLES”**

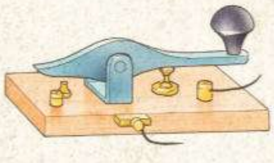
1833 ELECTRICAL TELEGRAPH

Radically changing the way that people communicated, the electrical telegraph helped connect the world like never before



The electrical telegraph was developed over a period of 40 years and worked by drawing together three key innovations. The first of these was the invention of the galvanometer by Danish engineer Hans Christian Ørsted in 1820. This allowed the strength of an electric current to be made visible through the deflection of an electric needle. The second innovation was the electromagnet, a device that provided a process for multiplying the magnetic force generated by a small electric current. The third and final innovation was the invention of the relay system in 1835, which could drastically amplify the strength of a signal.

Although the first electrical telegraph system was created by German scientists Karl Friedrich Gauss and Wilhelm Weber in 1833, Samuel Morse and Alfred Vail created a much more sophisticated telegraph four years later, as well as Morse code – a system of sending pulses of electrical current at different lengths down a network of metal cables. This led to the proliferation of long-distance communication throughout the U.S. and eventually the whole world, with the first successful transatlantic cable being laid in 1866.



1887

INDUCTION MOTOR

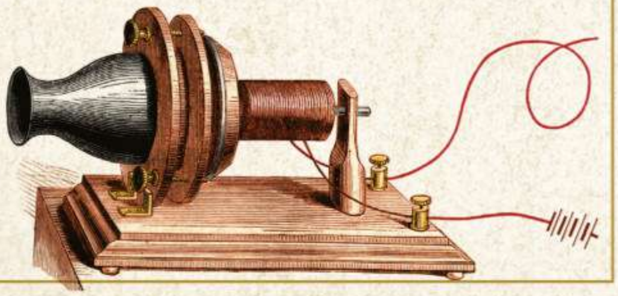
With this device Tesla took previous electric motors to a whole new level

Prior to Nikola Tesla’s invention of the polyphase induction motor, traditional dynamos had used a stationary stator to provide a constant magnetic field through which a set of rotating windings would turn. However, by reversing this process – so that the stator magnets rotated, rather than the rotor (windings) – current could be induced to flow through the latter with far greater efficiency. This was achieved by Tesla in 1887 with a two-phase induction motor that featured a rotating stator with two pairs of magnets – one pair for each two phases of alternating current (AC).

1876 BELL’S TELEPHONE

Alexander Graham Bell’s telephone brought acoustic telegraphy to the masses, allowing people to talk to one another over great distances

Alexander Graham Bell’s original telephone, patented in 1876, worked by converting sound into an electrical signal via a ‘liquid transmitter’. This process centred around directing sound through a receiver and onto a thin membrane stretched over a drum. On the outside of the membrane a cork with a needle attached to a battery extended to a cup filled with sulphuric acid and a metal contact. When sound waves hit the membrane it caused vibrations, varying the strength of the current passing between the needle and the contact. This created an electric signal of varying strength that travelled down a wire to a receiver, where through a reversed process the sounds were recreated. While not the only person to make a telephone at this time, Bell was the first to transfer his invention into a commercial product with a supporting network of exchanges and switchboards, etc.



1901

Marconi radio

Long-distance radio transmission becomes a reality with the invention of the radio telegraph and the radio by Italian Guglielmo Marconi.

1903

Wright Flyer

The Wright brothers launch their Wright Flyer – the first aeroplane to make a successful powered flight.

1908

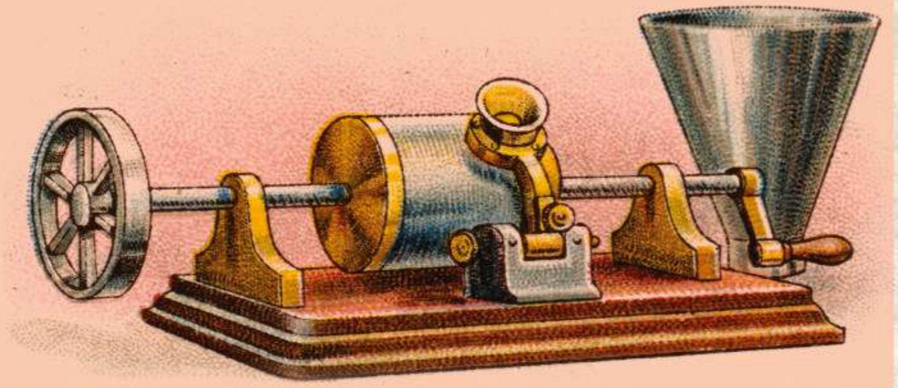
Ford Model T

Henry Ford introduces the production line and uses it to mass produce his now legendary Model T car.

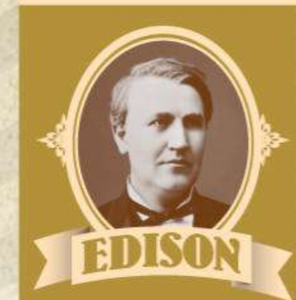
1877 EDISON'S PHONOGRAPH

An invention that resonates deeply today, Edison's 1877 phonograph ushered in an era of recordable and reproducible audio – the forebear of modern music players

The Edison cylinder phonograph was the first device in history that could mechanically record and then reproduce audio. It worked by receiving sounds through a brass mouthpiece and relaying them through a diaphragm to make it vibrate. The diaphragm's vibration caused a connected stylus to make indentations on a tinfoil-wrapped rotating drum. Once the tinfoil drum had been covered with indentations the received audio could be played back by passing a second stylus over them, making a second diaphragm vibrate to re-create the recorded sounds. The phonograph would eventually lead to the invention of the gramophone and disc-based storage, with LP (long-play) records becoming the dominant form of audio data storage until magnetic tape, which didn't emerge until the late 1920s.



KEY PLAYERS



THOMAS ALVA EDISON

Nationality: American

Role: Inventor

Born: 1847

Died: 1931

Known for: Carbon telephone transmitter, incandescent lamp, phonograph

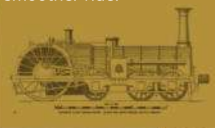
The U.S. inventor and astute businessman produced many devices still around today. As well as inventions he created a new system of electricity generation and distribution.

FOCUS ON THE GREAT EXHIBITION

1851's Great Exhibition typified the Industrial Revolution, showcasing a range of inventions and curiosities in a celebration of human ingenuity. Let's take a look at just a few of the exhibits and where they came from...

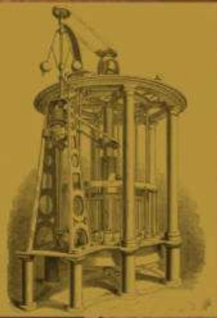
Express engine

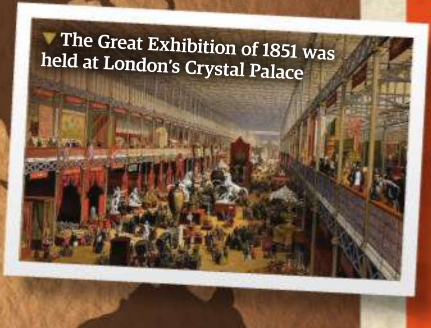
Displayed by the English South Eastern Railway Company, the express engine was a steam train with its engine suspended across three load-bearing struts. This allowed the weight to be evenly distributed over all wheels, granting a much smoother ride.



Double turbine

Made by Froment & Son, the double turbine offered many benefits over the standard water wheel. It featured "no accelerating gear", a drive shaft capable of a velocity of 100, 150 and 200 revolutions per minute and a one-piece propeller "that does not require repairing".

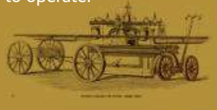




▼ The Great Exhibition of 1851 was held at London's Crystal Palace

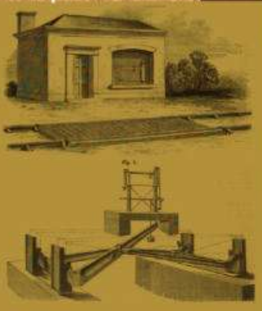
Fire engine

Created by G.J. Perry, this fire engine evolved the standard side-to-side pumping mechanism of contemporary engines with a large, end-to-end one. This increased the engine stroke from 20cm (8in) to 41cm (16in) and needed fewer firefighters to operate.



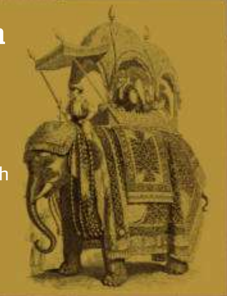
Weighing machine

Shown by Henry Pooley & Son, this device allowed a train's gross weight and rail impact to be measured while still on the track. It advertised an accuracy "equal to that of the beam and scales" and an "economy of labour, space and cost" improvement of roughly 50 per cent.

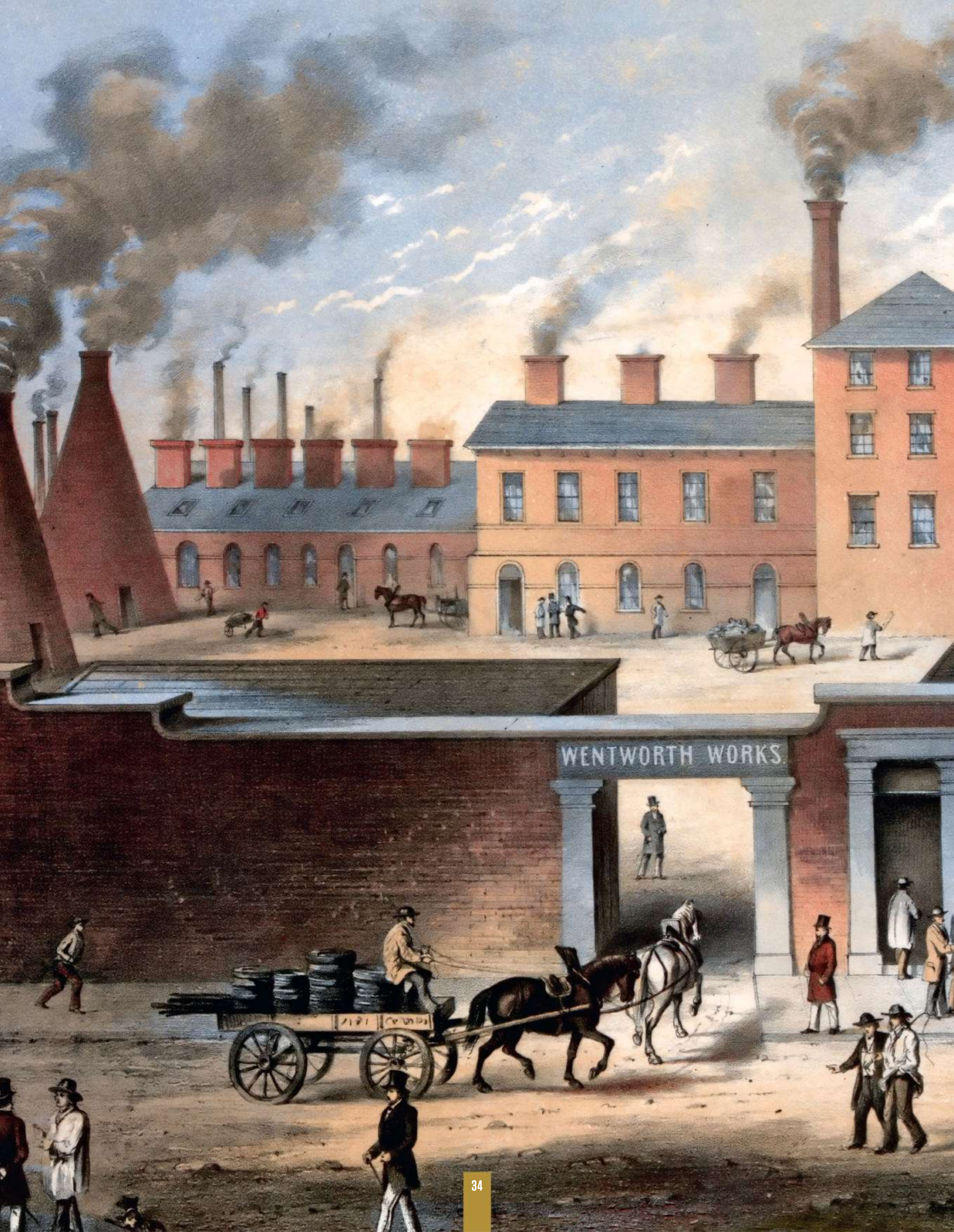


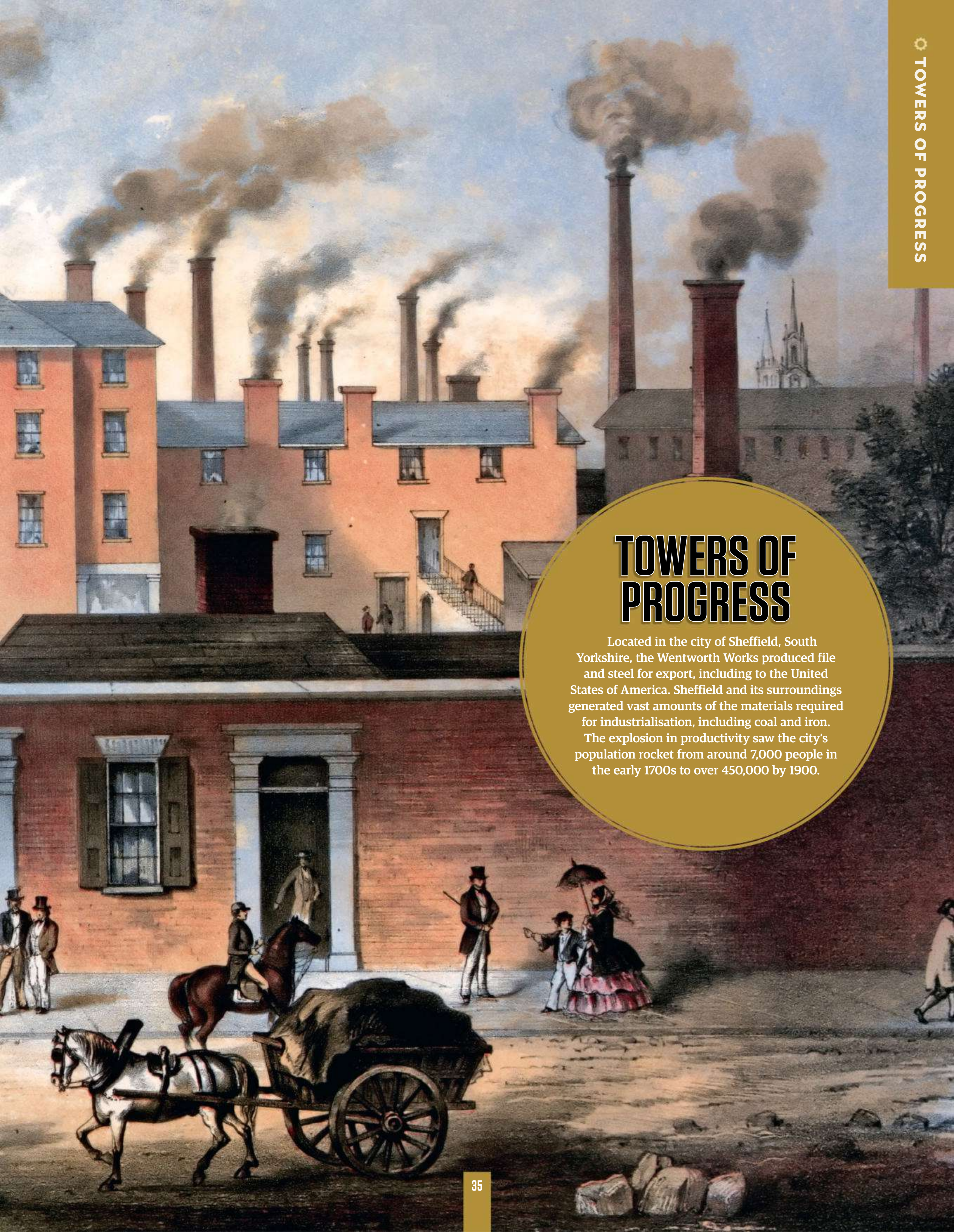
Indian howdah

Not everything at the Great Exhibition was a mechanical device. This Indian howdah (carriage) and elephant came courtesy of an Indian rajah and demonstrated the elaborate fixings needed to strap it securely to an elephant's back.



© SPL; DK Images; Alamy; Getty Images; Corbis


WENTWORTH WORKS.



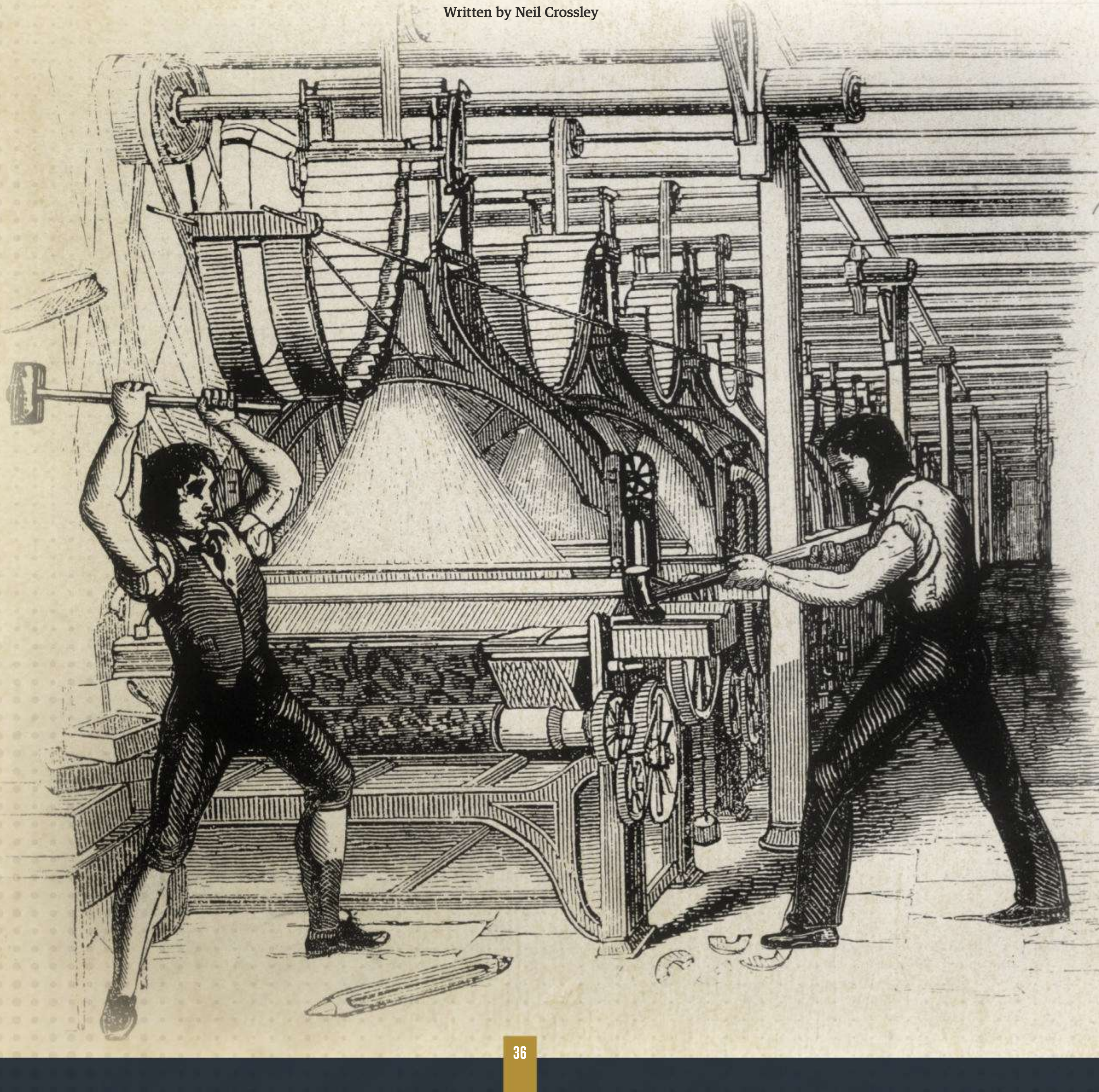
TOWERS OF PROGRESS

Located in the city of Sheffield, South Yorkshire, the Wentworth Works produced file and steel for export, including to the United States of America. Sheffield and its surroundings generated vast amounts of the materials required for industrialisation, including coal and iron. The explosion in productivity saw the city's population rocket from around 7,000 people in the early 1700s to over 450,000 by 1900.

RAGE AGAINST THE MACHINES

When their livelihoods were threatened by mechanisation, the textile-working Luddites rose up in anger

Written by Neil Crossley



It's a name that has passed into common parlance as a derogatory term for anyone who resists technological change, and yet the origins of the Luddites are far more complex than many people realise.

Over the course of a six-year period, from 1811 to 1817, the Luddites rose up in anger across the Midlands and the north as their very livelihoods as skilled artisan textile workers were threatened by the cost-saving introduction of mechanisation.

What followed was a highly organised and effective campaign of direct action marked by widespread protests and violence. Ultimately, the full might of the state and the military was brought down upon them, but the Luddites left a strong legacy. Their activities would pave the way for the creation of the first trade unions. Over two centuries later, with technologies such as AI posing an existential threat, parallels with the Luddites still resonate.

The Luddite movement came to prominence during the difficult economic period of the Napoleonic Wars. Wage bills were cut by employers, workers were sacked and machines were optimised to drive down costs. Luddites objected to the new mechanised textile equipment, which threatened the jobs of skilled workers by replacing them with a cheaper and less-skilled workforce. Skilled textile workers found themselves facing destitution.

The movement took its name from Ned Ludd, an apocryphal apprentice who allegedly smashed two stocking frames in 1779 after being criticised for his working methods, although it's doubtful that he existed (see above).

The village of Arnold in Nottinghamshire was the setting for the events that sparked the Luddite movement on 11 March 1811. On that day a group of Nottingham stocking knitters attacked a shop and destroyed 63 knitting frames. The frame-breaking incidents spread, and on 26 March 1811, the Nottingham corporation produced a handbill offering a reward of £50 to anyone supplying information about frame breakers, referring to them as "evil-minded persons" who had "assembled together in a riotous manner".

From the outset, though, the Luddites wanted to try and achieve their aims via peaceful means. They did their best to renegotiate for better conditions and wages while retaining a place in the new industrialised production process. Their requests included the introduction of a minimum wage, a commitment by factory owners to abide by minimum labour standards, and the creation of taxes to fund workers' pensions.

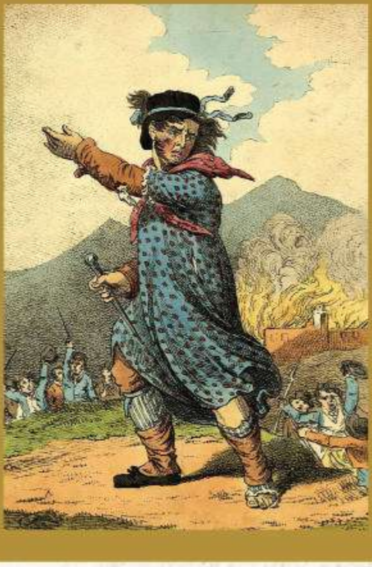
In addition to mechanisation threatening their livelihoods, the working conditions were very poor. The new machines were dangerous and serious accidents were not uncommon. But the government had seen to it that trade unions were outlawed by the introduction of the Combination Act of 1799. With no rights and no unions to represent them, the Luddites' requests were completely ignored by their employers.

◄ With no unions and bosses who ignored their concerns, the Luddites damaged machinery to try and get their point across

► Ludd was also referred to as General Ludd or King Ludd

GENERAL LUDD

Did the Luddites really base their whole movement around a fictional character?



Ned Ludd was a convenient figurehead and leader for the Luddites, but it's extremely doubtful he ever even existed. Like Robin Hood, he was said to reside in Sherwood Forest, organising the riots from a hut, but he was most likely a fictional character concocted from an incident that had supposedly taken place in a village near Leicester in 1779.

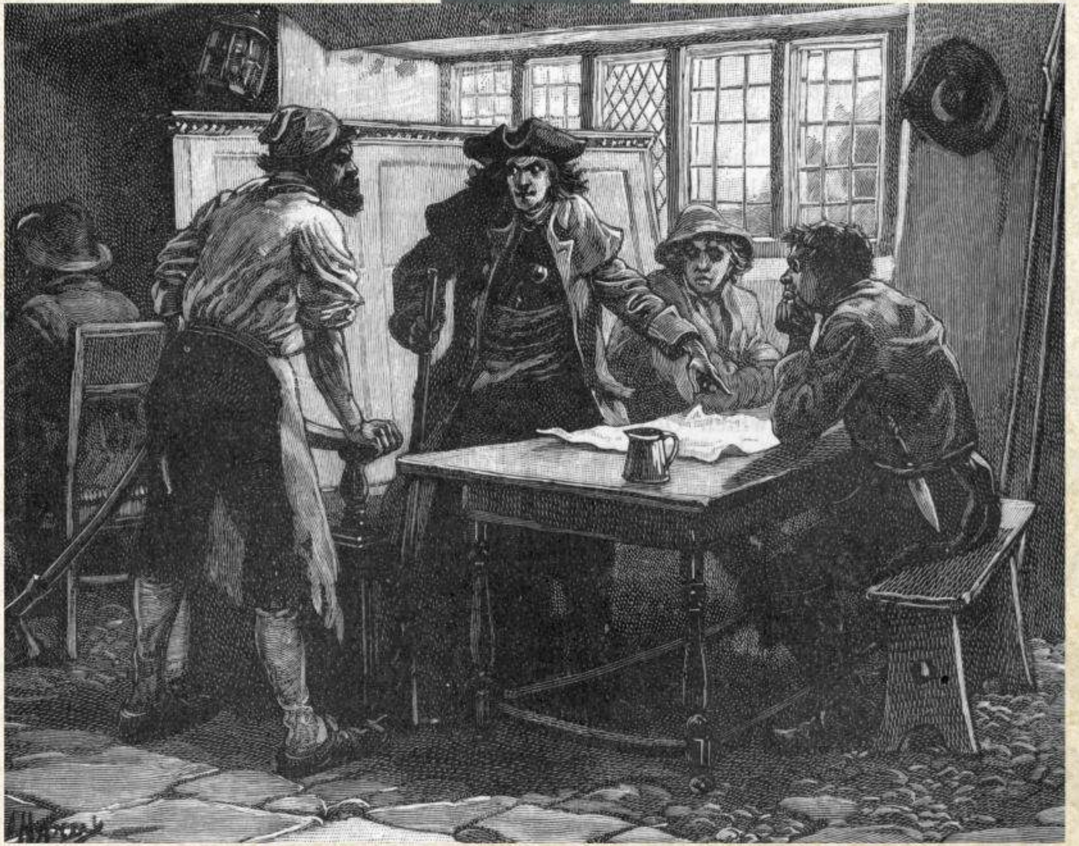
The story goes that a young apprentice called Ned Ludd smashed two stocking frames in a fit of rage after a superior admonished him for knitting too loosely.

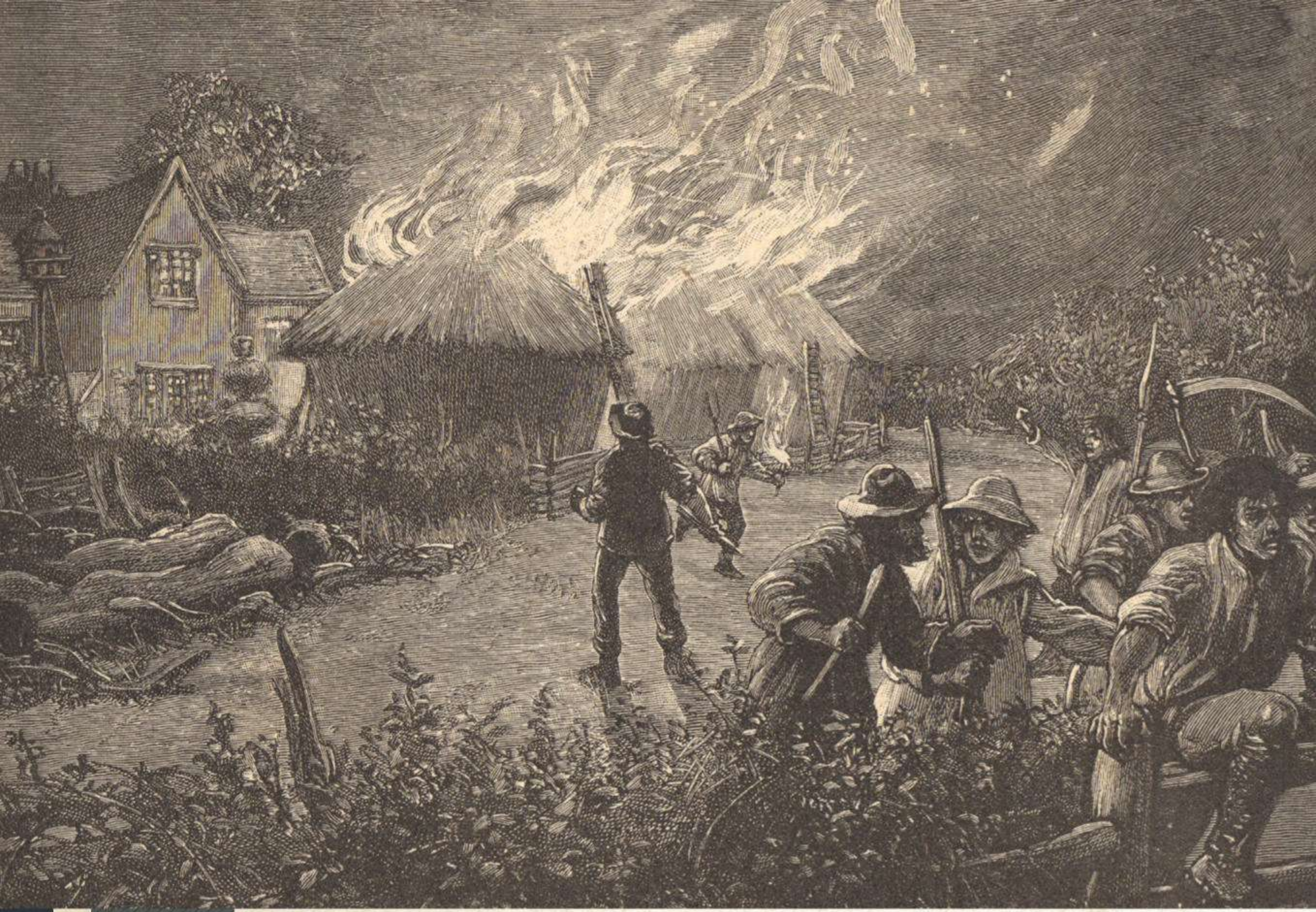
This story can be traced to an article in the *Nottingham Review* of 20 December 1811, but there is no independent evidence of its veracity. Similarly, a book entitled *History of Nottingham*, also published in 1811, refers to a young apprentice called "Ludlam" who was told by his framework-knitter father to "square his needles". Instead, the apprentice "beat them into a heap" according to the story.

Ludd was more likely a folkloric figure, but he fitted the Luddites' needs perfectly.

> "WAGE BILLS WERE CUT AND MACHINES OPTIMISED... WORKERS FOUND THEMSELVES FACING DESTITUTION"

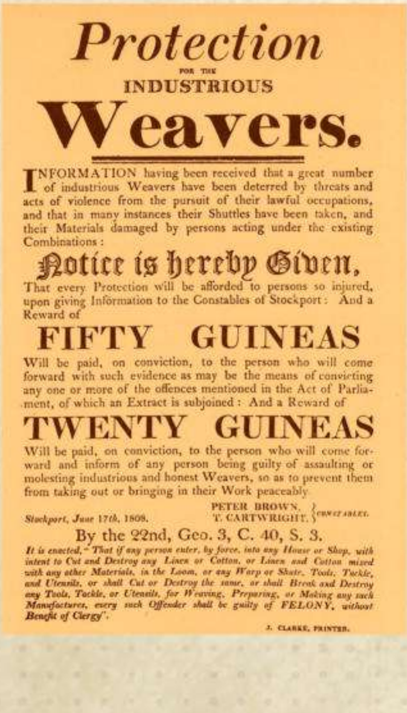
▼ Luddites plotting the overthrow of the government in the White Horse Pub in Pentrich





Aggrieved agricultural workers torch buildings and threshing machines in Kent

“THE AIM OF THEIR DIRECT ACTION WAS TO PUT EMPLOYERS UNDER PRESSURE SO THAT THEY WOULD BE FORCED TO CAVE IN TO THEIR DEMANDS”



Protection
FOR THE
INDUSTRIOUS
Weavers.

INFORMATION having been received that a great number of industrious Weavers have been deterred by threats and acts of violence from the pursuit of their lawful occupations, and that in many instances their Shuttles have been taken, and their Materials damaged by persons acting under the existing Combinations :

Notice is hereby Given,

That every Protection will be afforded to persons so injured, upon giving Information to the Constables of Stockport : And a Reward of

FIFTY GUINEAS

Will be paid, on conviction, to the person who will come forward with such evidence as may be the means of convicting any one or more of the offences mentioned in the Act of Parliament, of which an Extract is subjoined : And a Reward of

TWENTY GUINEAS

Will be paid, on conviction, to the person who will come forward and inform of any person being guilty of assaulting or molesting industrious and honest Weavers, so as to prevent them from taking out or bringing in their Work peaceably

Stockport, June 17th, 1808.
PETER BROWN,
T. CARTWRIGHT, } *CONSTABLES.*

By the 22nd, Geo. 3, C. 40, S. 3.

It is enacted,—“That if any person enter, by force, into any House or Shop, with intent to Cut and Destroy any Linen or Cotton, or Linen and Cotton mixed with any other Materials, in the Loom, or any Warp or Shute, Tools, Tackle, and Utensils, or shall Cut or Destroy the same, or shall Break and Destroy any Tools, Tackle, or Utensils, for Weaving, Preparing, or Making any such Manufactures, every such Offender shall be guilty of FELONY, without Benefit of Clergy”.

J. CLARKE, PRINTER.

The authorities offered rewards to anyone willing to help them apprehend Luddites. A guinea was worth one pound, one shilling (a shilling equates to 12p)

By 1812, Luddite activity had escalated in both occurrence and severity, spreading to Derbyshire, Leicestershire, Lancashire and the West Riding of Yorkshire. Luddites attacked and burned factories and became a highly organised movement, meeting at night on the moors that surrounded industrial towns. They attacked mills and factories and destroyed machines with sledgehammers. Gunfire was exchanged between guards hired by mill owners and Luddite groups.

The Luddites would always target machinery that posed a specific threat to their jobs. In Lancashire these were the steam-driven power looms; in Yorkshire they were the shearing frames and gig mills to finish woollen cloth; and in the Midlands they were the wide knitting frames used to make cheap lace items.

Contrary to popular opinion, Luddites were not violently opposed to technological change. As Brian Merchant notes in his 2023 book, *Blood in the Machine: The Origins of the Rebellion Against Big Tech*, the Luddites didn’t hate technology but rather “the way it was used against them”.

The aim of their direct action was to put employers under pressure so that they would be forced to cave in to their demands. In addition to the attacks, Luddites arranged public demonstrations and the mailing of letters to industrialists and government officials. These letters detailed their reasons for wrecking the machinery and threatened more raids unless use of “obnoxious” machines was halted. It wasn’t to be.

In 1812, the government passed the Frame Breaking Bill, which made the destruction of machinery punishable by death. Government spies infiltrated Luddite groups and things came to a head in April of that year.

From the government’s viewpoint the Luddite uprising had all the potential to escalate into a full-blown revolution. It was acutely conscious that only 23 years earlier the French Revolution had begun quietly before quickly degenerating into violence.

Britain was in the grip of an economic crisis and the harvests were bad, which paralleled the situation in France in 1789. Then, on 11 May 1812, further instability threatened to erupt when the prime minister, Spencer Perceval, was assassinated in the House of Commons.

A gauge of how seriously the government took the Luddites was reflected in the size of the military force that was deployed against them in April 1812. This force totalled 12,800 men, which was more than Wellington took with him when he sailed for the Peninsula in 1808 to recover Spain and Portugal from Napoleon.

The troops were commanded by Lieutenant General Thomas Maitland, a brilliant strategist. He began by rapidly assessing the extent of the discontentment and poverty, and within 48 hours of arriving in Manchester he had managed to send a comprehensive report to the Home Office.

His next task was to find the leaders of the Luddite insurrection. Maitland soon moved his headquarters to Buxton, which was closer to Yorkshire, where Luddite activity was more widespread.

One of the officers under Maitland's command, Captain Francis Raynes, began taking small forces out on moorland paths, where they surprised Luddite groups. Raynes' tactics were hugely effective. Within days his patrols were taking Luddite prisoners.

Luddites clashed with government forces on numerous occasions, but there are two events in particular that stand out as being pivotal to the movement's demise. The first occurred in the early hours of 12 April 1812, when over 100 men attacked Cartwright's Mill at Rawfolds, near the town of Cleckheaton, West Yorkshire. The group was led by George Mellor, a cloth dresser, or 'cropper', in the woollen industry.

Unfortunately for Mellor and his companions, the mill owner had been given advance warning of the raid and gathered his own troops. Two of the Luddite group were shot and killed in the ensuing clashes and the surviving Luddites were forced to flee.

Then, on 28 April 1812, mill owner William Horsfall was ambushed and shot by Mellor and three other men – William Thorpe, Thomas Smith and Benjamin Walker – near the village of Marsden in West Yorkshire.

Horsfall was targeted for having publicly stated that he would "ride up to his saddle in Luddite blood". He died from his injuries two days later. It was Mellor who had fired the fatal shot.

Reinforcement troops were sent to the area and the ringleaders were rounded up and sentenced to death. The state wanted a show trial to set an example that would weaken allegiance to the Luddite cause. In total, 64 Luddites (including Mellor) were transported to York Castle.

After four days of being relentlessly interrogated, one of the arrested Luddites, Benjamin Walker, agreed to turn King's Evidence for the state against his former comrades. His testimony would provide the framework for the Crown's case.

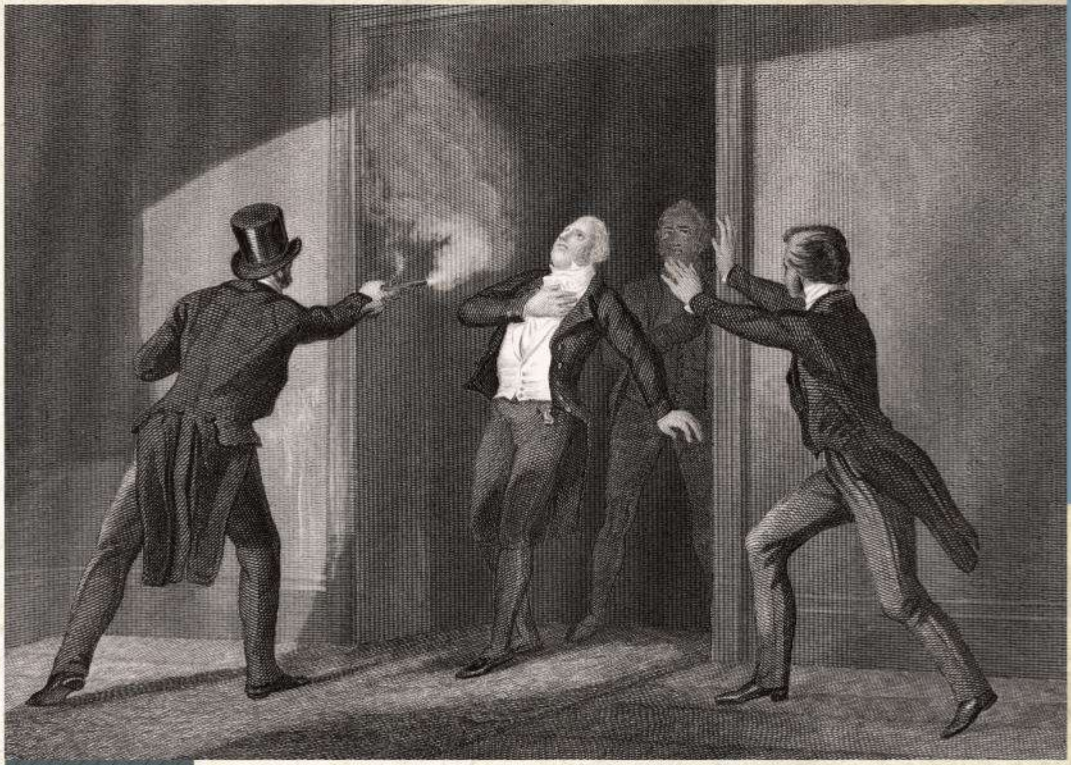
Ultimately, while many of the prisoners were acquitted due to lack of evidence, 17 of the men incarcerated in York Castle were hanged, with 14 of them going to the gallows on a single day, their grief-stricken families left penniless.

The army continued on its offensive to round up the Luddites, and those that weren't hanged were instead transported to penal colonies such as Australia to serve their punishment.

The state's brutal sentences were effective. By the end of 1813, direct action by Luddites had virtually ceased. But four years later, on 9 June 1817, an unemployed Nottingham stockinger called Jeremiah Brandreth led the Pentrich Uprising, which was the last major Luddite act.

Armed with scythes, pikes and a few guns, almost 300 men assembled near the village of Pentrich, Derbyshire. But within their midst was a government spy, William J. Oliver, and the uprising was over almost as soon as it had begun. Brandreth and co-conspirators Isaac Ludlam and William Turner were hanged and beheaded at Derby jail. Another, George Weightman, was sentenced to the same fate but had his sentence reduced to 'transportation for life' to an Australian penal colony.

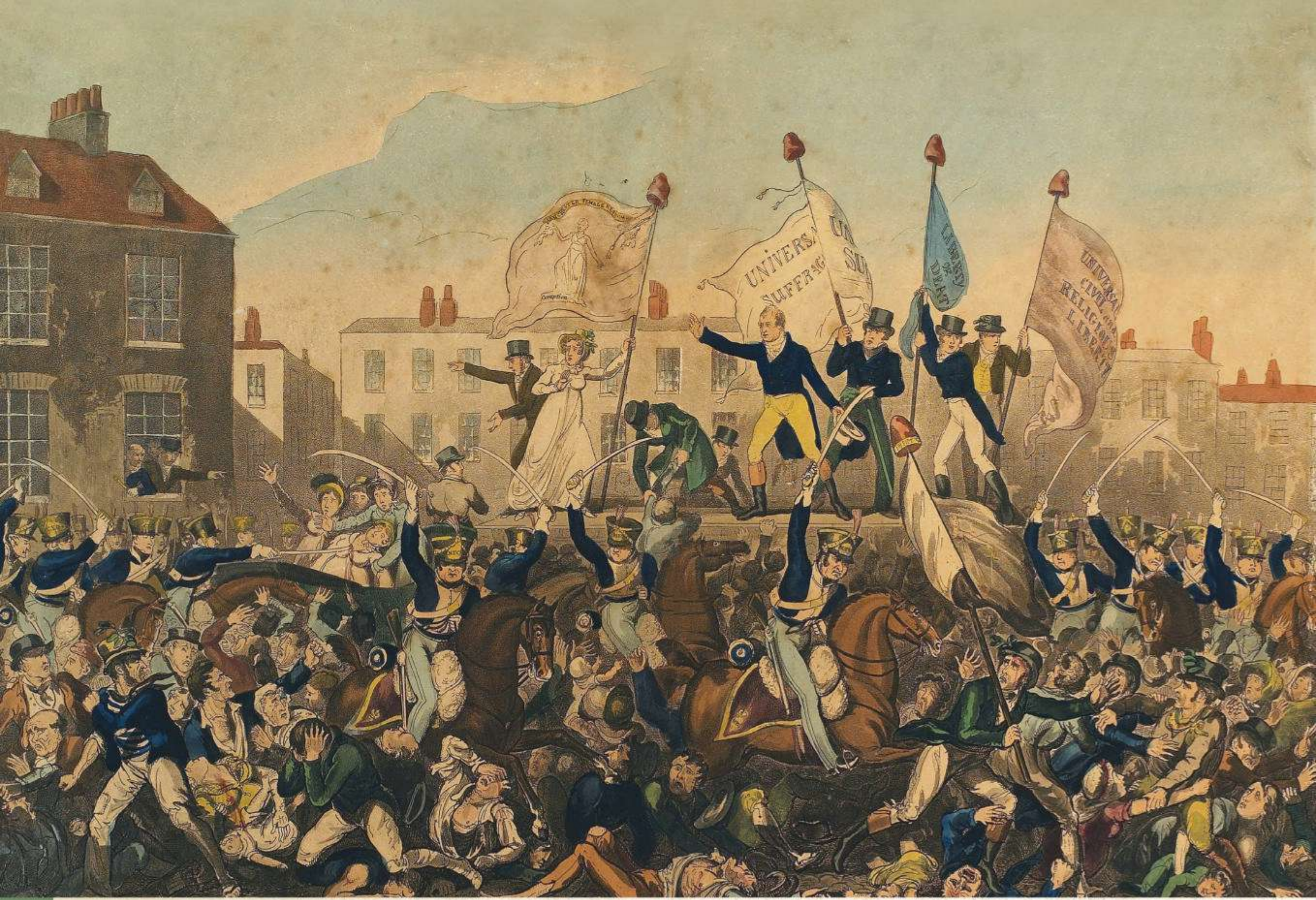
Over two centuries on, the legacy of the Luddites is largely diminished by their literal depiction as technophobes. In reality they were skilled, proud craftspeople facing destitution and fighting for their livelihoods in an age when there were no trade unions to protect them. In retrospect, the excessively brutal sentences meted out to them by the government of the day hardly suggests a nation hurtling into a prosperous, modern, industrialised future. Rather, it evokes a level of barbarity that is arguably more akin to the Dark Ages.



▲ John Bellingham fatally shoots Spencer Perceval, who remains the only British prime minister to be assassinated to date

▼ The Napoleonic Wars caused Britain's national debt to rise by almost £700 million and required huge hikes in taxes

© Alamy, Getty



REMEMBERING PETERLOO

We speak with historians, curators and campaigners about why it's so important we never forget the 200-year old tragedy of this protest for voting rights*

Written by Jonathan Gordon, Tom Garner

*This feature was written in 2019 to mark the 200-year anniversary of the Peterloo Massacre. Any events/exhibitions mentioned will no longer be running. However, the **peterloo1819.co.uk** website remains active

16 August 1819: between 60,000-80,000 men, women and children assembled in St Peter's Field in Manchester to protest for their right to parliamentary representation. Not long after Henry Hunt, the famed orator, took to the hustings the local magistrates ordered the arrest of Hunt and those leading the protest, and the Manchester and Salford Yeomanry charged the field, attacking with sabres as they met resistance from the crowd. With tensions rising they were followed by the 15th Hussars, who also charged having been ordered to disperse the assembly. What they seemingly didn't know was that exits had been blocked and most in the field were now trapped.

It's believed that 18 people died in the attack, including one two-year-old child, with over 500 injured. It was a shocking event that the press nicknamed "Peterloo" as an ironic reference to the Battle of Waterloo. John Lees, a former soldier and textiles worker, died from wounds he sustained and is reported to have told a friend before his death, "At Waterloo there was man to man but there it was downright murder." It's an event that echoed through the years that followed, but it would not be until 1832 and the Great Reform Act that anything close to what protestors called for would be put into law and over 100 years before universal suffrage would finally be achieved in Britain.

We spoke with some of the people looking to keep the memory of this event alive and why they think it is such an important moment in British history.

"BETWEEN 1819 AND 1832, THERE WERE SEVERAL HUNDRED PETITIONS SENT INTO PARLIAMENT FROM PEOPLE WHO WERE THERE DEMANDING AN INQUIRY"

PETERLOO AND MANCHESTER HISTORIES

▲ Mike Leigh's film, *Peterloo*, brought the events of 1819 to life with to the day of protest as well as the gruesome events that followed

KAREN SHANNON
Chief Executive

How long have you been working on the various events you have planned for the anniversary?
Manchester Histories and partners, which include both large cultural organisations and small community groups across Greater Manchester, have been working over the past four years on the programme that has led to Peterloo 2019. This has included running regular network and planning meetings to shape what activities take place and to develop the different strands of work such as the learning resources and the new website (**peterloo1819.co.uk**), which will also form part of the legacy for the project.

Did you have a particular mission statement for what you wanted to achieve for the anniversary?
Despite the scale of the Peterloo Massacre and the impact that it had at the time, both nationally and internationally, awareness levels have remained low. Peterloo is a chapter of our history that links directly to our present and events that followed like the Chartist and suffragette movements, with ordinary people campaigning for change. Our mission has been to make people more aware of the story and the relevance of Peterloo, to bring this to life and to explore the impact on society both then and now.

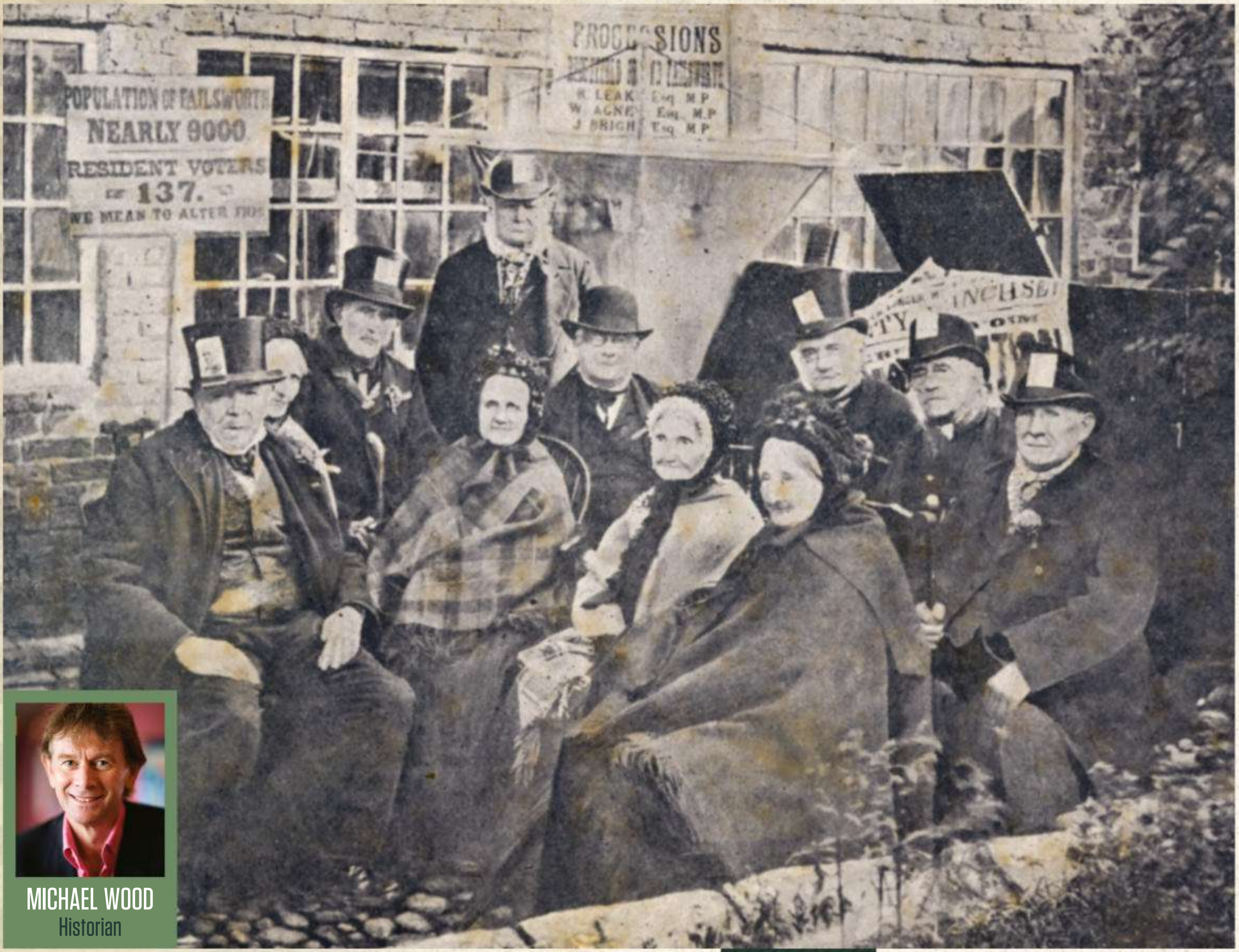
You've approached this anniversary in a multitude of ways, one of which is a broader series of events around protest and freedom of speech in the 200 years since Peterloo. Why did you choose to do that?
We want to make sure Peterloo has relevance to today and to influence people's future thinking in terms of finding out about their own and others' histories and heritage. The themes were chosen so that people could talk about their own interests today in parallel to the events of Peterloo.

By also looking more broadly at protest, it's given us the opportunity to not just focus on the story of Peterloo but also other important events that have shaped our society today, like the Greenham Common Women's Peace Camp [established in 1981] that peacefully protested for nuclear disarmament.

What does Peterloo mean to the city of Manchester?
I think the commemorations to date have been very emotive. The Peterloo story unleashes a rawness, it stirs deep feelings of pride, anger, and highlights people's struggles to be represented. People have really connected to this and to each other through discussions and attending different events. It means Manchester is still a city that has lots to say and is proud of its radical roots and spirit!

▼ St Peter's Field has since been built over, but Free Trade House is now roughly in that location

THE PETERLOO VETERANS


POPULATION OF FAILSWORTH
NEARLY 9000
RESIDENT VOTERS
137.
WE MEAN TO ALTER THIS
PROCESSIONS
R LEAK Esq MP
W AGNE Esq MP
J BRIGH Esq MP
FRANCHISE

MICHAEL WOOD
Historian

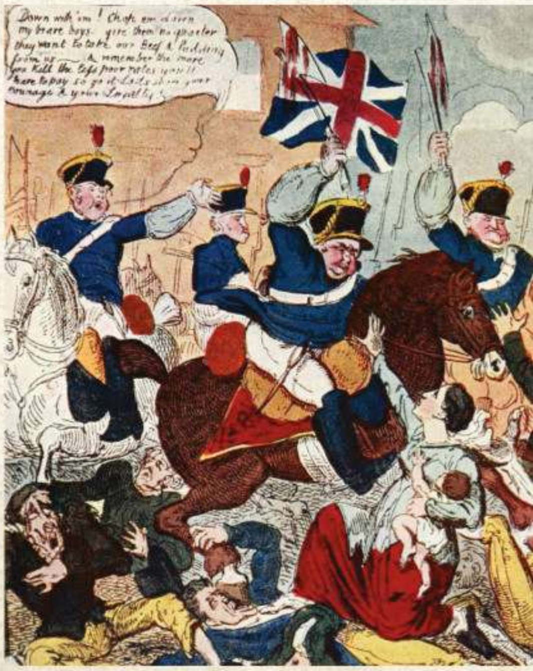
▲ **The Peterloo Veterans, 27 September 1884: David Hilton, Thomas Chadderton, John Davies, Thomas Ogden, Jonathan Dawson, Susannah Whittaker, Mary Collins, Catherine McMurdo, Richard Waters, Thomas Schofield, Alice Schofield**

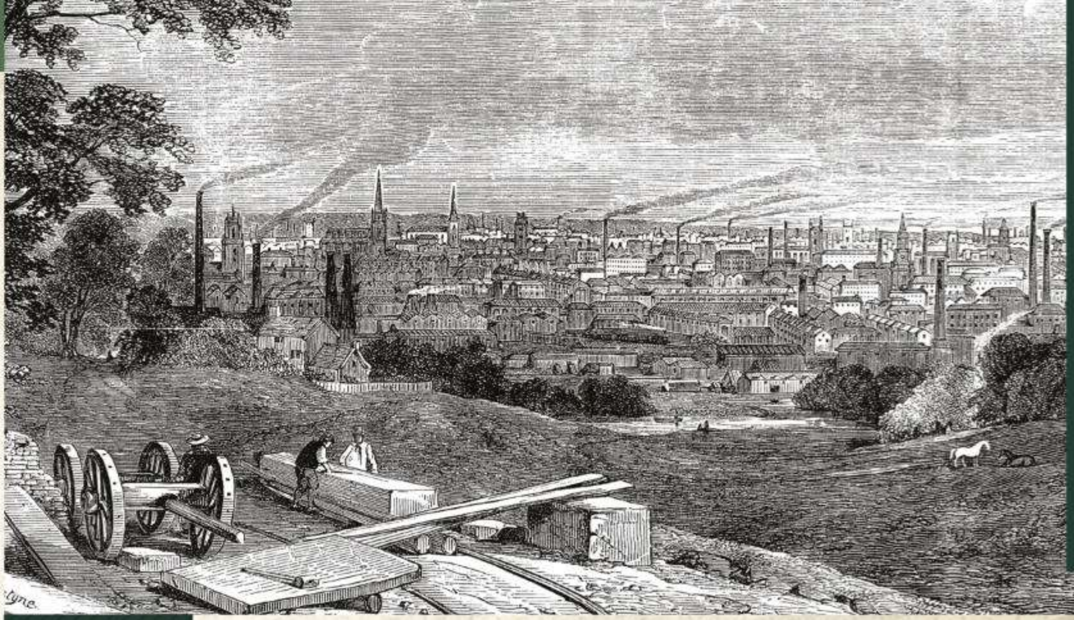
On 27 September 1884, an extraordinary photograph was taken of 11 elderly survivors of the Peterloo Massacre. Aged between 79 and 83, these protestors were still campaigning for better voting rights. A copy was discovered by historian and television presenter Michael Wood in a collection of old history books that belonged to his father. He recently gave a lecture about the image called 'The Peterloo Photograph' as part of Manchester Histories' bicentenary commemorations. We spoke to Wood about the massacre's powerful legacy in the city and beyond.

What did the march to St Peter's Field say about the condition of Manchester at the time?
There were massive divisions emerging with poverty and unemployment. The Industrial Revolution was underway and there were a lot of stresses and strains on society. Manchester was also a really difficult place to operate in. There was no civic order and it was still under a manorial ownership.

How important was the massacre as a political event?
One historian said that Peterloo was "up there with Magna Carta", so it was a massive moment and everybody recognised it. The leadership had instructed the protestors that there was to be absolutely no violence used or any semblance of rioting. There were a large number of women present, and Samuel Bamford described many of them as wearing white dresses and frocks with hats and garlands of flowers. The whole atmosphere was like Wakes Week with the festive summer entertainments that they put on in rural districts.

Everybody was therefore totally stunned by what happened. The government moved against reforming newspapers as


Down with 'em! Chop em down my brave boys: give them no quarter they want to take our Beef & Pudding from us — & remember the more you kill the less poor rates you'll have to pay so go it Lads show your courage & your Loyalty!



▲ The growth of Manchester as the world's first city of the Industrial Revolution influenced many radical thinkers and movements including Karl Marx, the Chartists and the Suffragettes

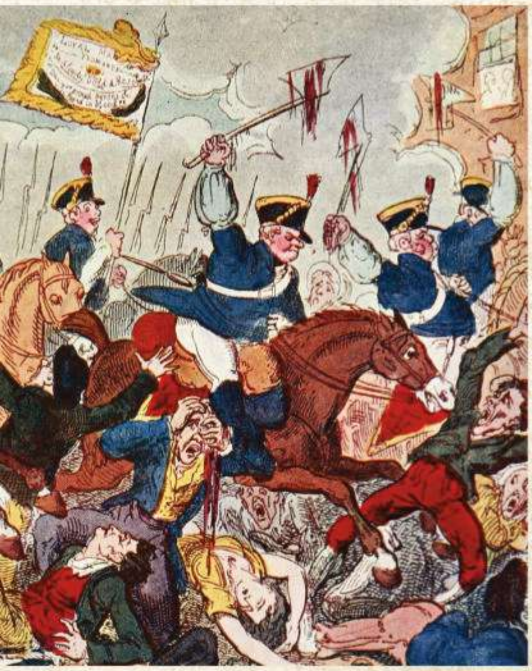
often as it could but everybody was writing about it. Alison Morgan has just published a collection of Peterloo songs and ballads and she's retrieved about 80 to 90 of them! These were written in the immediate aftermath and sung in pubs, clubs and taverns. *The Manchester Guardian* (now *The Guardian*) was also founded in the aftermath of Peterloo.

How was Peterloo remembered when you were growing up in Manchester?
Everybody knew about Peterloo in our neck of the woods. Certainly when I went up to Manchester Grammar School when I was 11 the history teacher made a speech on the first day. He gave us his pen-portrait of Manchester, which was a city of free trade, the Industrial Revolution and the heroes and heroines of Peterloo.

It was definitely something that we all knew about, and in my particular case my father came from Failsworth, which played quite a role in the Peterloo story. It was a famous centre of radicalism, and it was a really well-known story in our family because we've got ancestors tracing back there to at least the 1790s.

How did a copy of the 'Peterloo Photograph' come into your family?
These were 11 veterans who were youngsters at the time and they were all part of the Failsworth story. Our families were linked to a pool of people, including a few of the veterans, who went to Peterloo who were all neighbours, friends and related by marriage.

I should say that I'm no expert and these are simply family stories. As I was clearing out my mum's house after she died three years ago I found a box of books belonging to my dad that included photos and other odd and ends. We wondered why there were these old, obscure local history books of Failsworth among them and they all carried the photograph of the Peterloo veterans. My dad had kept three or four books that contained the picture because it was taken in Failsworth at a very prominent event.



◄ Contemporary artwork depicting the tragic events

What do we know about the photograph?
The account of the meeting from 1884 says that they carried a banner that they'd carried with Samuel Bamford's detachment to Peterloo. However, the two banners that you can read were from a demonstration for the vote that they had attended in 1884. There they are in their 80s and they are still fighting! They were still activists, and that night they went round to a local house for tea where they told stories and sang songs.

How important are photographs like this as historical records?
Photographs sometimes open an amazing window. There is quite a famous photograph in the British Library of a Chartist meeting in 1848 in Kennington, and when you have photos like that it's staggering. They are beyond price as a record of what people were actually like at that time during the early development of photography.

Photos can therefore be absolutely stunning and it's why I called my talk 'The Peterloo Photograph'. This is because you may think, "Peterloo? 1819? Photography wasn't invented then!" But there they are and we know who they were and what they did. They're no longer anonymous weavers who don't have any background or can't be placed.

How important are the bicentenary events for Manchester?
I think they are important and Manchester has always had a unique place in history.

► The original Failsworth Pole, where people gathered, has since been replaced by a clock tower

When you travel in on the train from Stockport it doesn't have the vibe of a great city of history or a place of destiny. However, because of what happened from the Industrial Revolution onwards, it was no mistake that so many movements began there. This included the suffragettes, and Chartism was really big in Manchester. It was a great centre of radical and liberal politics, and Friedrich Engels lived there, which is why Karl Marx came up.

It was really the experience of Manchester that led Engels and Marx to construe the nature of capitalism in the way that they did. If Engels had lived in Birmingham Marx would have seen a completely different kind of industrial society. It was made out of thousands of small workshops and it was a different kind of industrial economy altogether. Their interpretation of history was really influenced by Manchester.

Peterloo is ultimately a symbol, an electric moment after which nothing can be quite the same again. Mancunians still feel that and I think that's reflective of the pride they have in their city as a crucible of history where things are hammered out.

LEGACY OF PETERLOO

DR SHIRIN HIRSCH

Researcher at the People's History Museum and lecturer at Manchester Metropolitan University

The Disrupt? Peterloo and Protest exhibition at People's History Museum (PHM) is putting the Peterloo Massacre at the heart of a conversation about protest and collective action. Why was that important?

At People's History Museum (PHM) we wanted to remember the Peterloo Massacre as a critical event in modern Britain. But we also wanted to connect Peterloo with the present and future of protest and collective action rather than just a history lesson we wanted to think about how Peterloo influenced and inspired a much longer history of protest and resistance.

Did Peterloo set the stage for further protests for voting rights in the years that followed?

In the years following the massacre the government cracked down on protest. When Percy Bysshe Shelley heard of the massacre, he penned the poem *The Masque of Anarchy*, powerfully indicting those who were responsible. Yet Shelley could not find a publisher brave enough to print his words, with the genuine threat of imprisonment hanging over radicals in this period. It was only in 1832, after Shelley's death, that the poem was first published. Out of the ashes of Peterloo and following the Great Reform Act of 1832 a new working class movement emerged with the Chartists, and they would continue the struggle for voting rights that had been violently repressed at Peterloo.

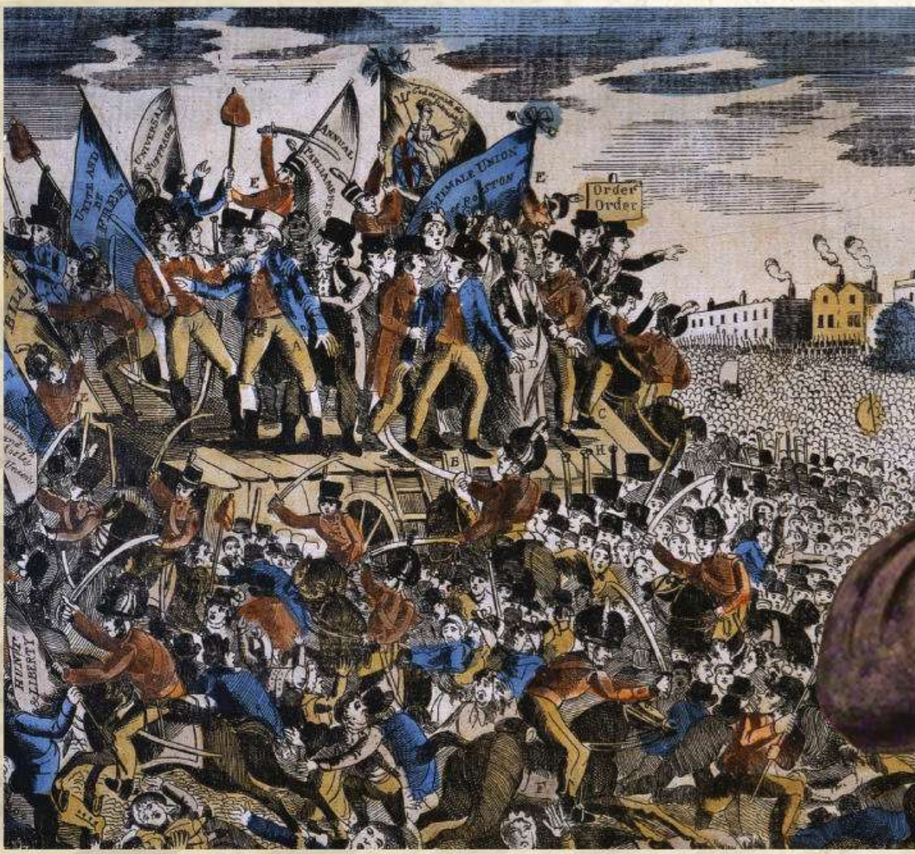
Did the crackdown have a lasting effect on the memory of Peterloo?

Ordinary people continued to keep the memory of Peterloo alive. There were a huge number of protestors, around 60,000, who had witnessed the massacre and they refused to forget. In our collections and galleries at PHM, and now on show in our exhibition Disrupt? Peterloo and Protest, we hold many of these commemorative artefacts: handkerchiefs, jugs, flags and medals all made to continue the memory of Peterloo. But the repression that followed the massacre certainly means that many of these objects from the reform movement have now been lost or destroyed.

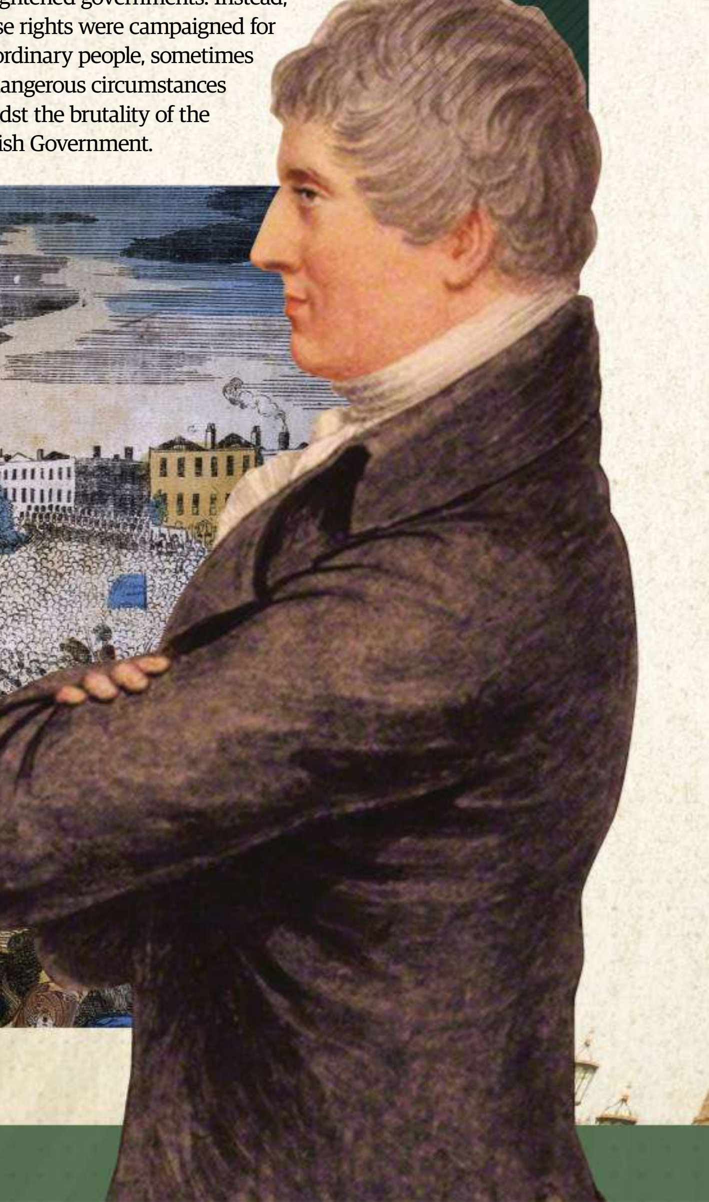
What do you feel Peterloo can teach us about modern protest?

The protestors who met at St Peter's Field powerfully represented the real communities of Manchester and its surrounding towns and villages. There were many women at the demonstration, and they often led their sections into the march. Women were critical to the reform movement, yet, just as now, they were mocked and targeted as they stepped out of their role as wives and mothers. Peterloo teaches us that the campaign for women's rights did not simply begin with the suffragettes. But the Peterloo Massacre also tells us that rights we have today, like the vote, were never simply given to us by enlightened governments. Instead, these rights were campaigned for by ordinary people, sometimes in dangerous circumstances amidst the brutality of the British Government.

> "PETERLOO TEACHES US THAT THE CAMPAIGN FOR WOMEN'S RIGHTS DID NOT SIMPLY BEGIN WITH THE SUFFRAGETTES"



▲ Thanks to Manchester being at the heart of the economic transformation of Britain it was also a hotbed of energised citizens looking to make their voices heard



▼ Henry Hunt was a popular orator for the cause of parliamentary reform. He was arrested at Peterloo and imprisoned for two years

THE VIEW FROM WESTMINSTER

DAVID PRIOR
Head of Public Services and Outreach, Parliamentary Archives

What can visitors expect to find at the Parliament & Peterloo exhibition?
The Parliament & Peterloo exhibition, which opens on 4 July at Westminster Hall, really tells the story of how Parliament and Peterloo are connected. We look at the background of Peterloo and the state of the country immediately after the Battle of Waterloo. We also reference the beginnings of people campaigning for the right to vote.

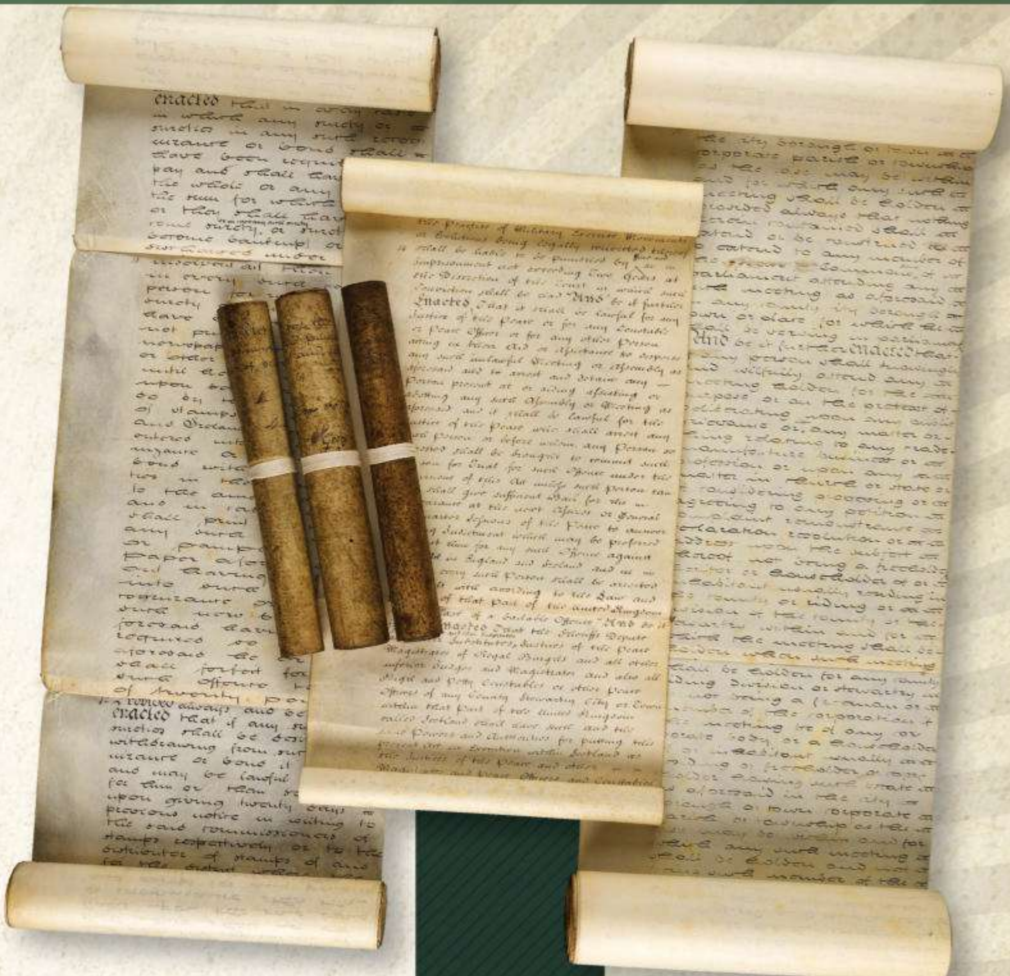
One of the features we're having in the exhibition is an audiovisual presentation. We've been working in partnership with Royal Holloway University of London and they supplied us with some videos that bring to life some of the testimony of people who were around at the time. For instance, we have a video of someone who speaks the words of a woman called Mary Fildes who was actually one of the people on the platform with Henry Hunt at Peterloo.

What do we know about Westminster's understanding of what was happening in Manchester?
Because it was August, parliament wouldn't have been sitting at the time. Parliament as a body wasn't immediately aware of what was happening, but what happened subsequently was a series of reports and copies of letters from people who were there at the time.

Between 1819 and at least 1832 there were several hundred petitions sent into parliament from people who were there demanding an inquiry.

Has the process of digitising your archive shed any new light on the response of parliament to Peterloo?
I think the papers we've found that are in the bundle marked 'papers relating to the internal state of the country' have possibly been overlooked by historians in the past, simply because of the way they've been catalogued here. There's a lot of personal testimony that I think sheds light on the way people were treated at the event.

Are there any examples of testimony that spring to mind?
Mary's is the testimony that I'm most aware of, and hers is that she was struck by someone, treated very badly by a member of the Yeomanry, and they were the ones who charged into the meeting. She describes how that happened and how other people around her were basically hit and injured by the action of the Yeomanry and the cavalry. And it took her several days, if not weeks, to recover from the experience.



▲ The Six Acts, passed in 1819, were a direct response to the growing activism that had been showcased at Peterloo

▼ Record-keeping at Westminster dates back as far as 1497 and includes bills, motions and more from both the House of Commons and House of Lords

> "SHE DESCRIBES HOW OTHER PEOPLE AROUND HER WERE HIT AND INJURED BY THE YEOMANRY"

A PERMANENT MEMORIAL

▲ The Peterloo Massacre Campaign held a number of events to bring more attention to Peterloo, such as this gathering with protestors carrying the names of the 1819 victims

PAUL FITZGERALD

Peterloo Massacre Campaign chairman

How did the campaign for a permanent memorial to the victims of the Peterloo Massacre get started?
I'm a professional political cartoonist and was drawing a cartoon that used Tiananmen Square as a metaphor about the rise of capitalism and consumerism in China and kept getting this weird feeling that it reminded me of something... but what?

Then the penny dropped. It's Peterloo. I very quickly began asking why Manchester has no memorial to an event that changed Britain and the world. We know why the regime in China wouldn't commemorate Tiananmen, but what excuse did my home city have?

About the same time some delegates at the Labour Party annual conference, which was being held very near the site of the massacre, were wandering about in a break, seeing if they could find any indicators of what happened there, and couldn't. We ended up joining forces with them after our launch.

What have been the biggest challenges to getting approval for the memorial?
It was a pretty open door in terms of the basic yes to the idea. The really big challenge was to push the council to make sure there was a genuine and of course profoundly appropriate democratic input into what the design should consist of, and that was a nightmare of anger and frustration. They exerted a really shocking level of control over it, and despite our efforts to pressure them, they revealed the design and held a token consultation in late 2018, too late for any serious objections or revisions. Since then we've all been drowning in bitter irony at how undemocratic the process of choosing a memorial to democracy has been. It's all very telling, eh?

How was the final design concept for the memorial decided upon?
We pushed hard for an open design competition, but ultimately it would seem very few people in the council hierarchy had a yes or no say about artist Jeremy Deller's design. We did, however, manage to get our 'RIP' criteria for the memorial incorporated into the process: Respectful, Informative and Permanent/Prominent, and I think those have been met. But it seemed to take a formal Freedom of Information demand to pry that inner door open.

How well-known are the events of Peterloo to the people of Manchester?
Until recently, it was the norm not to know about it in the city. There really has been a 200-year whitewashing of its memory. We hope our persistence over the years has helped combat that and that Mike Leigh's film does the same.

You've just published a graphic novel about Peterloo. What can you tell us about that project?
Yeah, it's all come round in a circle regarding my 'day job'! Myself, Eva Schlunke and historian Professor Robert Poole recently finished *Peterloo: Witnesses to a Massacre*. We deeply hope it'll prove a very accessible and populist way for people to find out more. Just researching it was an amazing experience.

◀ Artist Jeremy Deller unveils plans for his Peterloo memorial

Much of the text is actually from reporting and government correspondence from the day. Why did you choose this approach?
Everything in it, in a white narrative or speech bubble, is simply 100 per cent accurate and taken from the huge range of sources that exist; courtroom transcripts, spy's reports, journals, diaries and so on. They alone, without the images, make for an astonishing and moving read, with deeply contrasting attitudes from the huge range of characters. We think this may be the world's first 'verbatim' graphic novel!

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FROM OPIUM DENS TO FREAK SHOWS, DISCOVER THE SINISTER SIDE OF THE VICTORIANS

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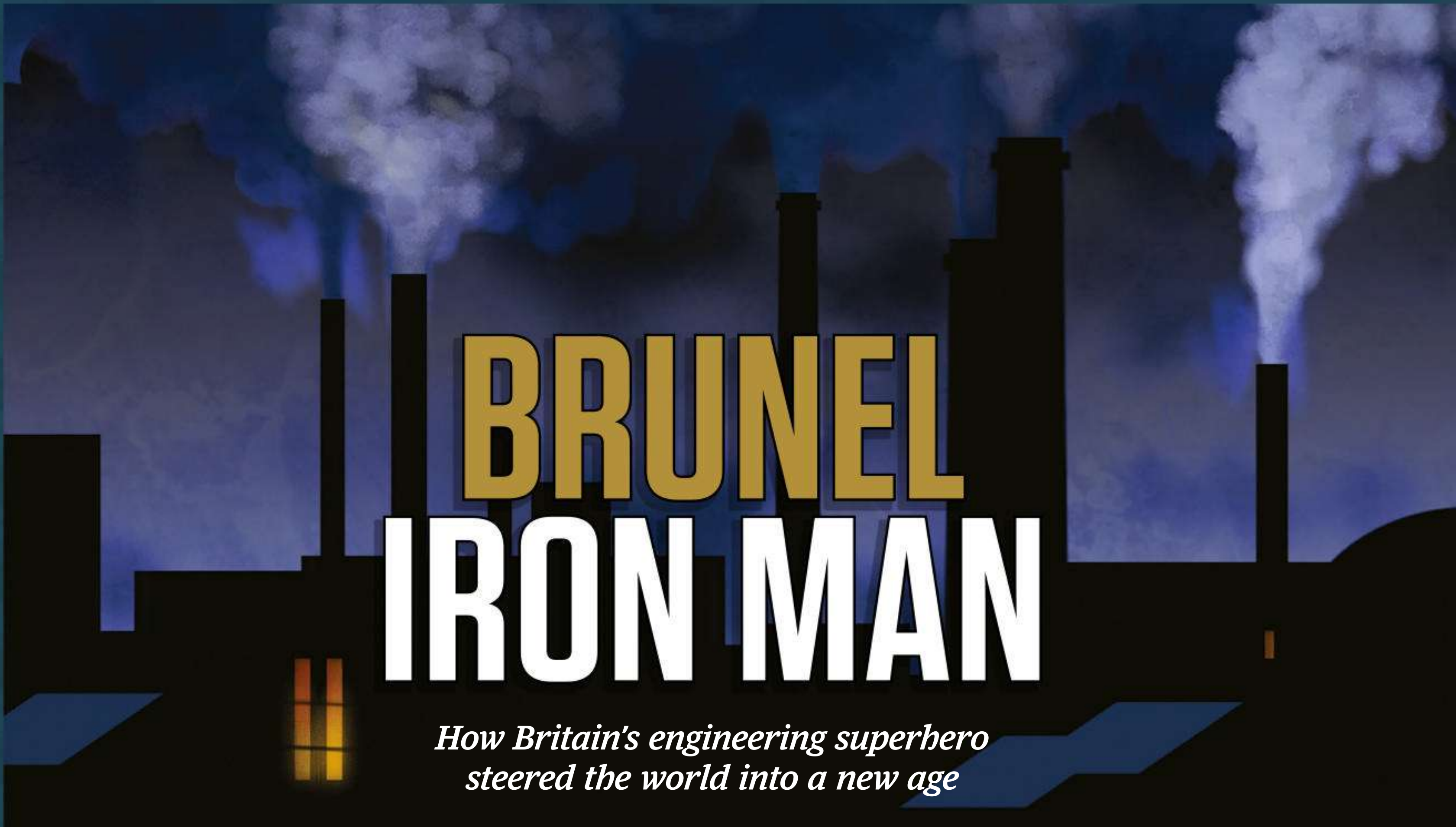


BRUNEL
IRON MAN

How Britain's engineering superhero steered the world into a new age

With the accession of Queen Victoria came the end of an era. The dramatic changes to home and work life brought about by the First Industrial Revolution were now the norm, and Britain's landscape had been forever altered. Rather than the patchwork of fields and farms her grandfather had ruled over, Victoria's Britain was a booming industrial centre.

The invention of the spinning machine had revolutionised textile production, and cotton mills now littered the country. The invention of the steam engine had freed these machines from the limitations of water power, meaning factories could now be built anywhere – and the owners had chosen the cities. Workers swarmed in from the countryside in search of jobs, and cities grew at an unprecedented rate. Between 1801 and 1850, Manchester and Sheffield quadrupled in size, and Bradford and Glasgow grew eightfold.

With this new demand for steam power came a greater demand for coal. Mines were made deeper, and production increased from 2.4 million tonnes in 1700 to 45 million in 1850. Then came the steam train, hauling coal around mines and delivering raw materials to factories. Britain was soaring above the rest of the world; it seemed it could go no higher.

But a new revolution was dawning – a technological one. Developments in the field of metallurgy meant that materials like iron and steel could now be made at low cost and high efficiency. Railways were snaked around the country, and huge load-bearing bridges stretched spans previously deemed impossible. The shipbuilding industry boomed, as new materials and technologies meant that ships could now be built to endure the long, perilous journey across the Atlantic. Then, an English scientist called Michael Faraday made one of the greatest discoveries in history when he found that an electromotive force could be created by moving a wire through a magnetic field. The principle, known as Faraday's Law, opened up the possibility of a world that was powered not by coal but by electricity. By the end of Victoria's reign, Britain had turned electric.

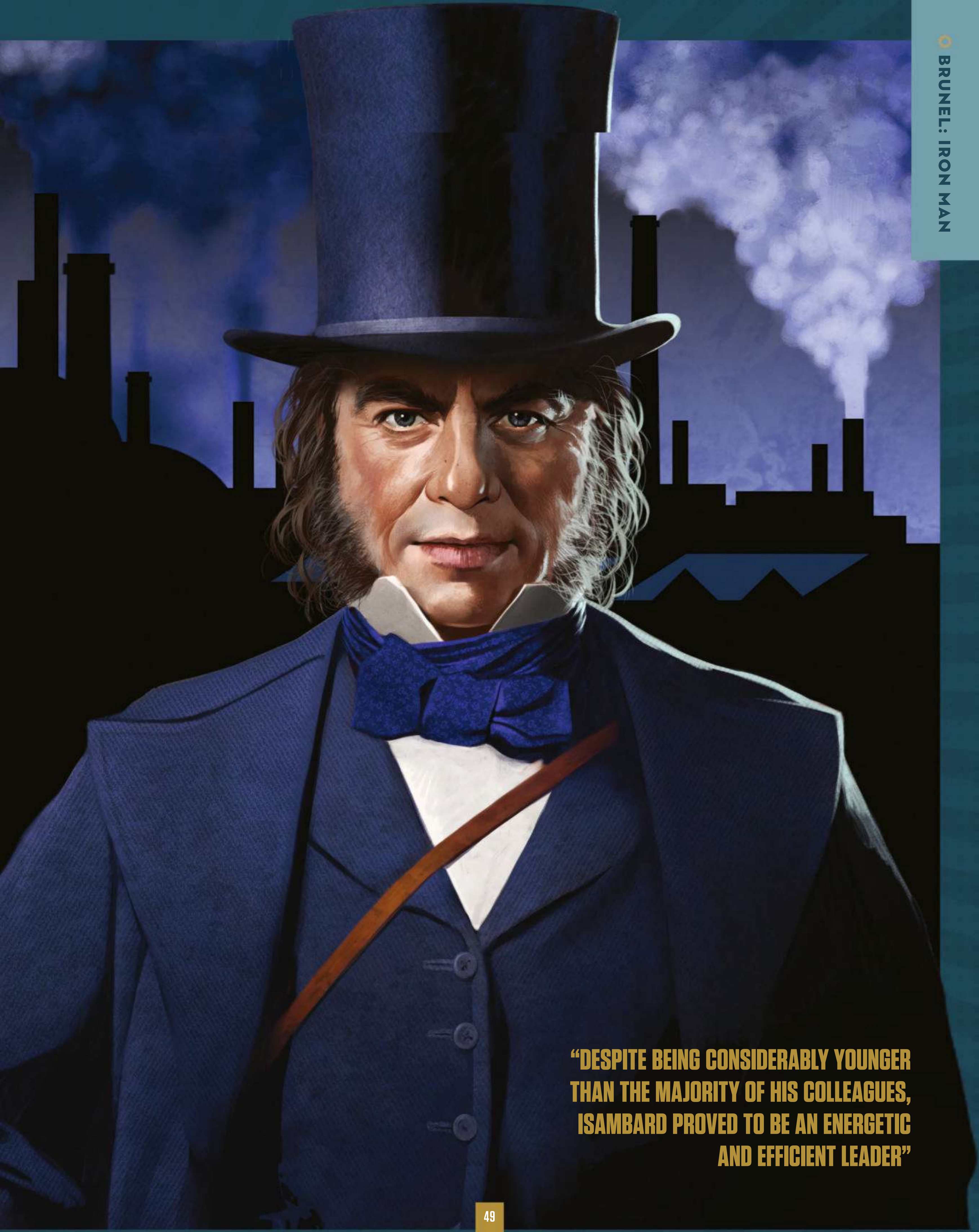
The Industrial Revolution was a pivotal moment in the evolution of Britain into a world superpower. It was a time of tremendous transition and upheaval, with the country becoming more productive and connected than ever before. It gave individuals with the relevant capacity and wherewithal the chance to showcase their talents – one such person was Isambard Kingdom Brunel.

Born on 9 April 1806 in Portsmouth, he was the son of Sir Marc Isambard Brunel, himself an engineer of some renown. Having had an affluent upbringing, Marc was determined that Isambard receive a similarly good education. After imparting upon him a solid grounding in engineering principles, he sent him to a French academy to gain experience first-hand before returning to work as an assistant for his father.

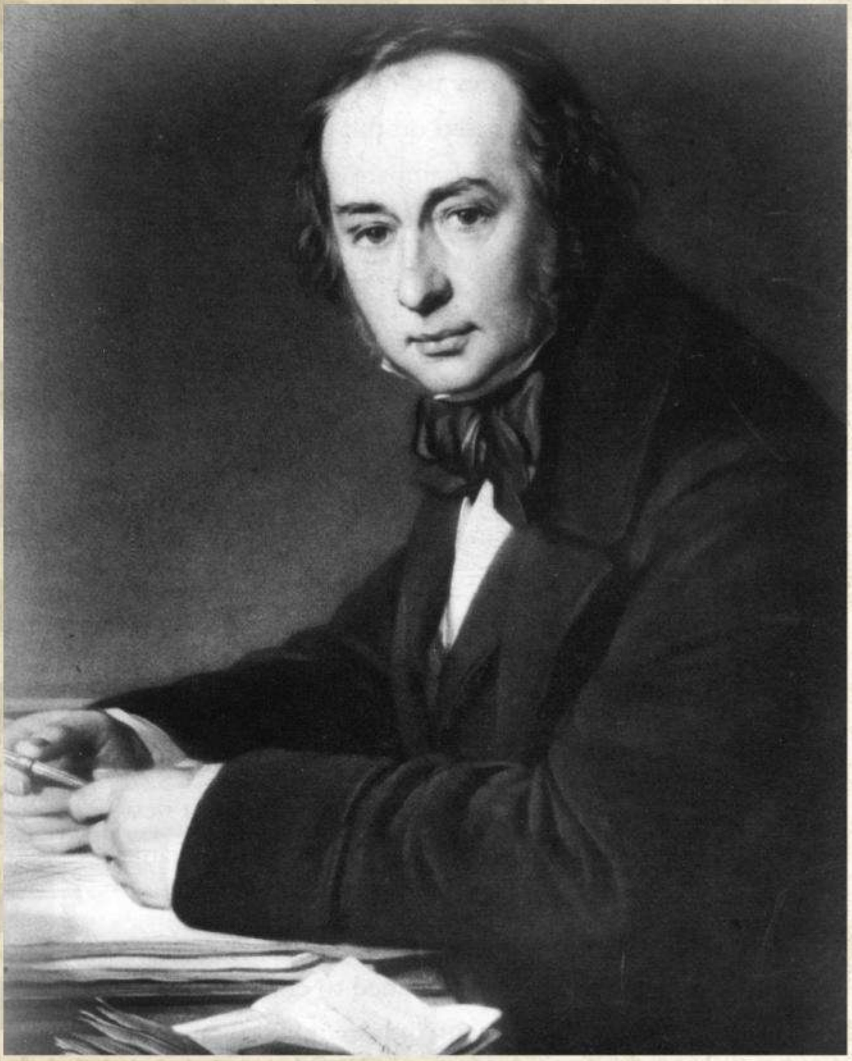
It was shortly after this, in 1825, that he would take on his first role of real responsibility, serving as assistant engineer on a project to construct a tunnel underneath the River Thames. Despite being considerably younger than the majority of his colleagues, Isambard proved to be an energetic and efficient leader, driving the project forwards – often in the absence of his father, who was preoccupied with other issues and his own poor health. However, the work was dangerous, which Isambard discovered soon enough.

After initially escaping a tunnel flooding on 18 May with no loss of life, a much more serious accident occurred on 12 January 1828, killing six and nearly fatally injuring Isambard. He was hospitalised and the project was postponed, but nonetheless it provided him with vital experience.

The following year, Isambard was drawn to Bristol by a competition to design the proposed Clifton Suspension Bridge, which was to run over the River Avon. His design was chosen, causing him to remark: "I have to say that of all the wonderful feats I have performed since I have been in this part of the world, I think yesterday I performed the most wonderful. I produced unanimity among 15 men who were all quarrelling

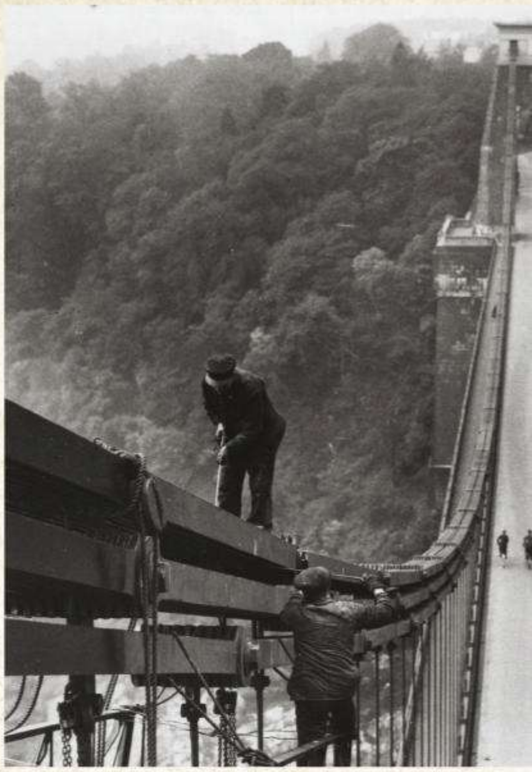


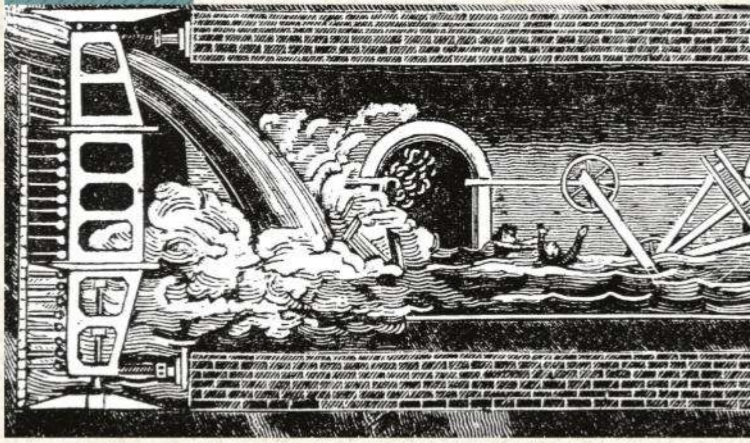
"DESPITE BEING CONSIDERABLY YOUNGER THAN THE MAJORITY OF HIS COLLEAGUES, ISAMBARD PROVED TO BE AN ENERGETIC AND EFFICIENT LEADER"



A 2002 poll by the BBC placed Brunel 2nd on the list of 100 greatest Britons

Brunel was incredibly fortunate to survive the Thames Tunnel collapse in 1828





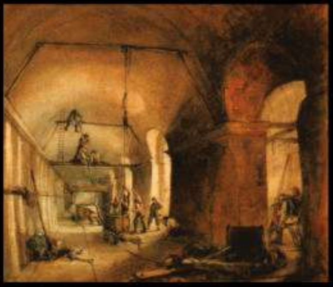
> “THE RAILWAYS HAD OPENED UP A WHOLE NEW WAY OF LIFE TO THE BRITISH PEOPLE”

Timeline

Defining moment

Thames Tunnel collapse
12 January 1828

While working on the Thames Tunnel, 21-year-old Brunel almost dies when part of the tunnel floods. Six men lose their lives and Brunel suffers a badly injured leg and internal injuries, being saved only by prompt action from fellow engineer Richard Beamish. He is sent off to Brighton to recuperate, only for the illness to relapse, and he doesn’t recover until the spring. In the meantime, work on the tunnel grinds to a standstill – the project wouldn’t be resumed until 1834 and remained unfinished until 1843.



Defining moment

Chief engineer of Great Western Railway 1833

Brunel is appointed chief engineer of the proposed Great Western Railway, intended to link London with Bristol. After an act of Parliament in 1835, work begins on the project, with Brunel taking a hands-on role. Along the way a great many long-standing bridges, viaducts, tunnels and other landmarks are constructed, such as the Box Tunnel, Paddington Station and the Hanwell and Chippenham viaducts. It arguably remains Brunel’s most notable legacy, with much of his work remaining intact today.

1806

Born
Isambard Kingdom Brunel is born in Portsmouth, the son of Sophia Kingdom and French-born engineer Marc Isambard Brunel, whose footsteps he will go on to follow.
9 April 1806

1820

Attends college in France
At 14, Brunel is sent to France to study. He first enrols at the College of Caen in Normandy before moving on to the Lycée Henri-IV in Paris. At 16 he returns to Britain.
1820

1829

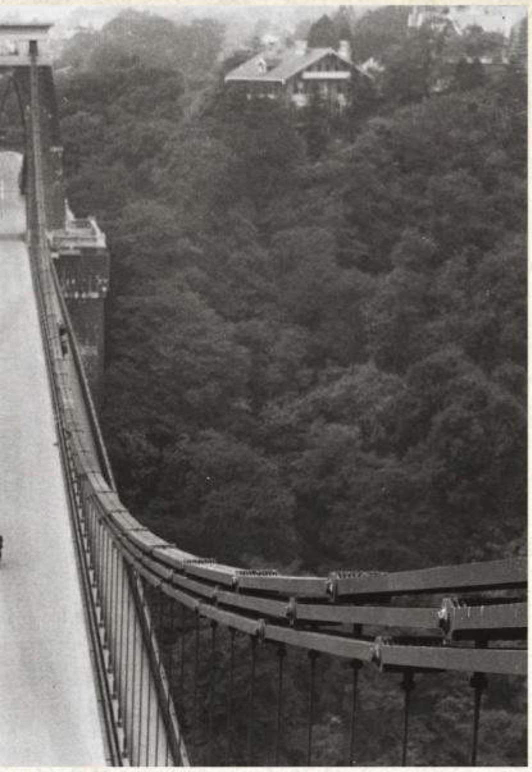
Designs Clifton Suspension Bridge
While in Bristol, Brunel successfully designs what will go on to become the Clifton Suspension Bridge. Due to various delays, it won’t be completed in his lifetime.
1829

1836

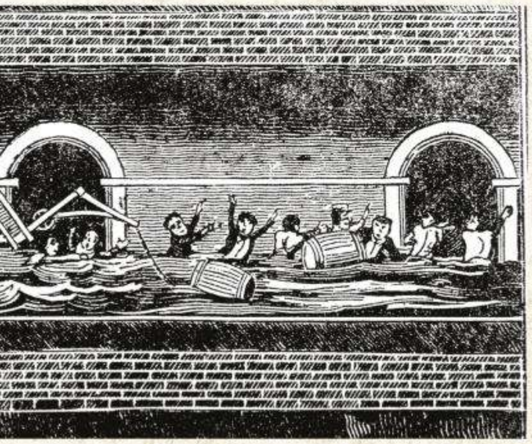
Marries Mary Elizabeth Horsley
Brunel marries Mary Elizabeth Horsley – the daughter of noted musician William Horsley – in London. Their marriage is a happy one, and they go on to have three children together.
5 July 1836

1838

SS Great Western maiden voyage
Then the biggest ship in the world, the vessel sets off from Bristol for its maiden voyage to New York. Brunel is injured when a fire breaks out in the engine room.
31 March 1838



Although Brunel designed the Clifton Suspension Bridge, it was not built in his lifetime

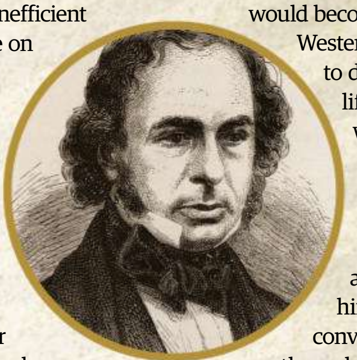


about that most ticklish subject – taste." Unfortunately, the project was interrupted and ultimately halted by the effects of the Bristol Riots of 1831, but Brunel's skill had got him noticed.

CONNECTING THE COUNTRY

The First Industrial Revolution had seen the invention of a new method for smelting coal, and the coke pig iron it produced was used for making cast-iron goods like pots and kettles and later as a building material. It revolutionised metallurgy, but it was an inefficient process impractical for use on a wide scale. However, in 1828, Scottish inventor James Beaumont Neilson patented a design for a hot blast technique that drastically reduced the amount of fuel required for the process. In turn, the cost of producing the wrought iron necessary for making things like train tracks fell, allowing for the proliferation of railways in the 1830s.

Though the first steam trains had been designed in the early 1800s, they had mainly been used in coal mines and for transporting goods. The first public steam-hauled railway – the Stockton and Darlington – opened in 1825, and the first inter-city railway in the world was opened in 1830, connecting Liverpool and Manchester. Then, in an event that would change rail travel forever, the first section of the Great Western Railway was completed in the year of Victoria's accession to the throne.



The project had been masterminded by merchants in Bristol, who wanted to ensure that the city remained the second most important port in the country and the chief one for American trade. They decided the way forward was to build a railway line between Bristol and London, one that would outperform those being built in the north.

In 1833, Brunel was appointed chief engineer for the Bristol Railway project and immediately set to work. Over the next ten years Brunel's work on what would become known as the Great Western Railway would come to dominate his professional life. While other railways were built in stages, from the beginning Brunel conceived the project as a whole.

Brunel completed a vast amount of the surveying himself, going against convention to choose a route through the Vale of White Horse (providing better access to Oxford, Gloucester and the north), connecting London to Reading via Paddington (for which he would design the station), and Bath to Bristol by way of the Avon Valley. After some opposition, an act of Parliament was passed in 1835 allowing the building work to commence.

It was by far Brunel's biggest project to date, and it was to be plagued with controversies. The most infamous was Brunel's decision to use a 2.14-metre (seven-foot) track gauge, known as a broad gauge. He decided on this gauge with the future of rail travel in mind, foreseeing

Defining moment

SS Great Eastern transatlantic maiden voyage 17 June 1860

Of all the projects he worked on, the SS *Great Eastern* proved to be the most trying. Going over budget and overdue, it quickly became an ordeal, with Brunel frequently clashing with shipbuilder John Scott Russell. After a number of mishaps (the first launch in 1857 failed, and the maiden voyage to Weymouth in 1859 resulted in a boiler explosion that killed six), it made its maiden transatlantic voyage in 1860 to New York.

The SS *Great Eastern* never completed its journey to Australia

1841

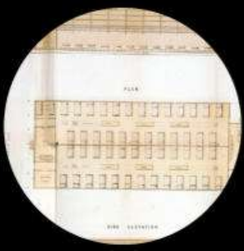
- **Great Western Railway completed**
  Eight years after Brunel was appointed as its chief engineer, the full route of the Great Western Railway is finally completed.
  June 1841

1843

- **SS Great Britain floated out**
  The 2,738tn, 98m (321.5ft)-long SS *Great Britain* floats out into Bristol City Docks – then waits 18 months so the dock can be widened before it can leave.
  19 July 1843

1848

- **Chartist crisis**
  During the events of the Chartist crisis in London, Brunel enrols as a special constable in Westminster.
  May 1848

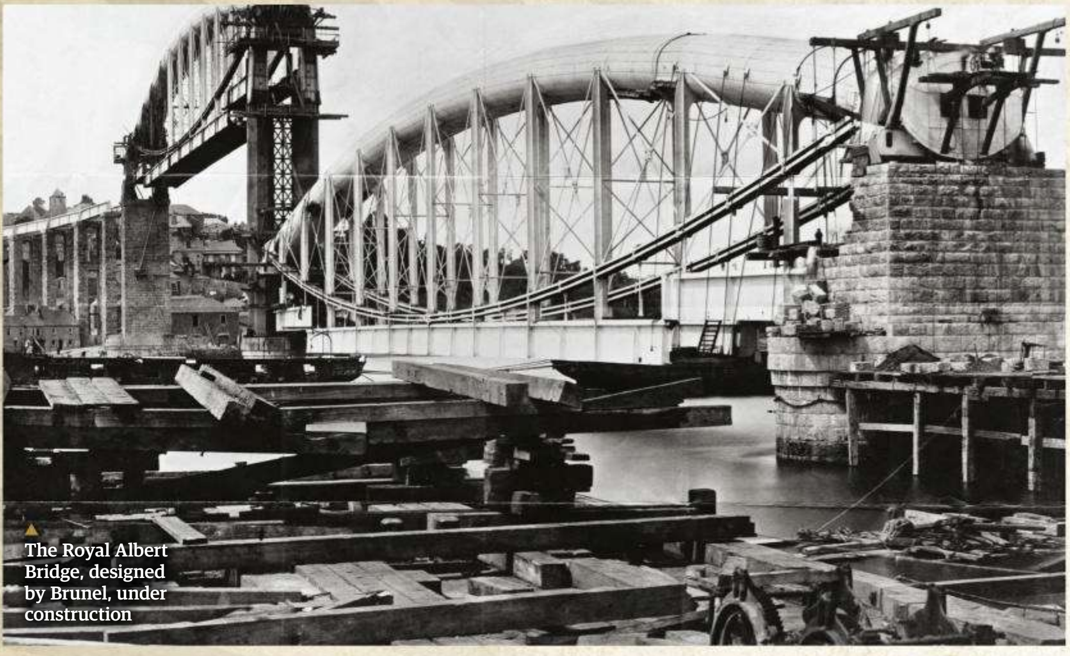


1855

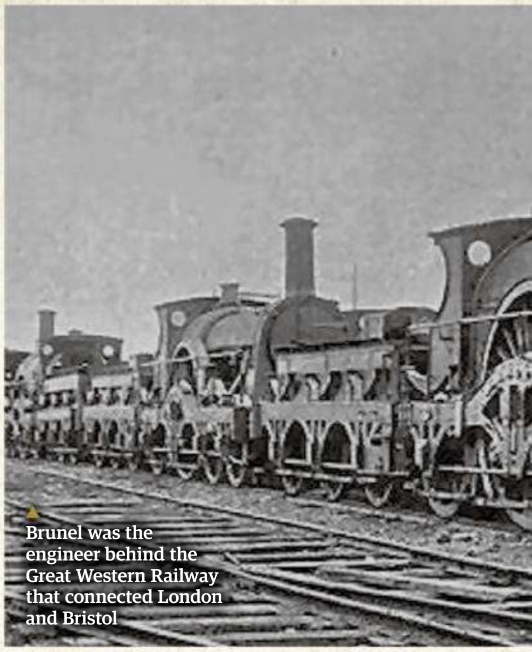
- **Renkioi Hospital**
  Brunel starts to design prefabricated hospital shelters to be stationed at Renkioi in the Dardanelles during the Crimean War. Careful attention is paid to heating, ventilation, drainage and sanitation.
  February 1855

1859

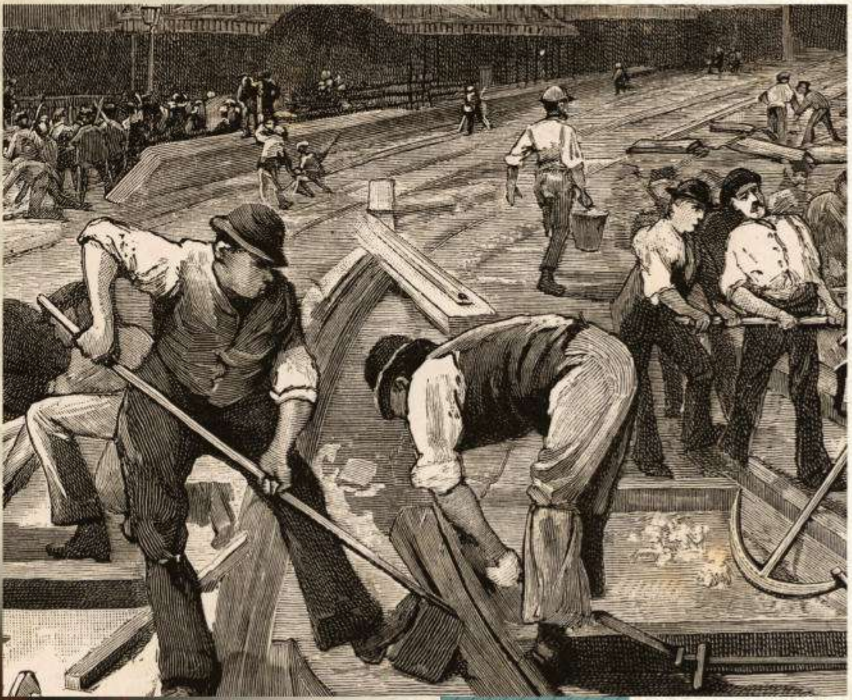
- **Passes away**
  Ten days after suffering from a stroke, Brunel dies at the age of 53. Like his father, he is buried in the Kensal Green Cemetery in London.
  15 September 1859



The Royal Albert Bridge, designed by Brunel, under construction



Brunel was the engineer behind the Great Western Railway that connected London and Bristol

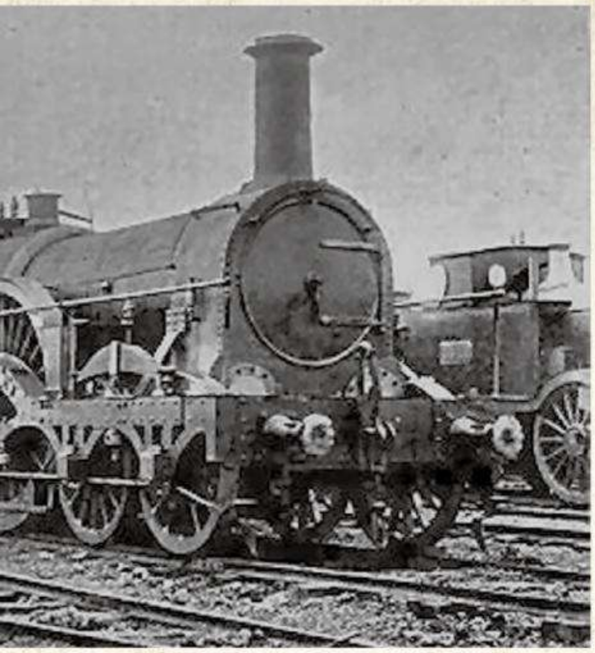


Broad gauge tracks being ripped up in Plymouth after Parliament ruled in favour of the standard gauge

that high-speed trains would need wider, lower carriages to reduce air resistance. However, the Birmingham and Gloucester railway had already been built with a standard gauge measurement of 1.435 metres (4.7 feet). This meant that when the line would eventually be connected to the broad-gauge Bristol and Gloucester line, all passengers and goods travelling between the north and the south west would have to change trains halfway through their journey. This problem sparked the 'gauge war', which was eventually battled out in Parliament.

The first section of the new track – from Paddington to Maidenhead – was opened on 4 June 1838, incorporating the Wharncliffe Viaduct, the first in a series of similarly impressive structures. The route was extended to Twyford in July 1839, then Reading in March 1840, through the Vale of White Horse to Wootton Bassett by December 1840, down into Chippenham in May 1841 and finally on to Bristol in June. This last section of the route was delayed due to difficulties with the construction of the 1.1-kilometre (1.75-mile)-long Box Tunnel, which in turn produced a knock-on effect with delays to the completion of the Bristol–Bath route.

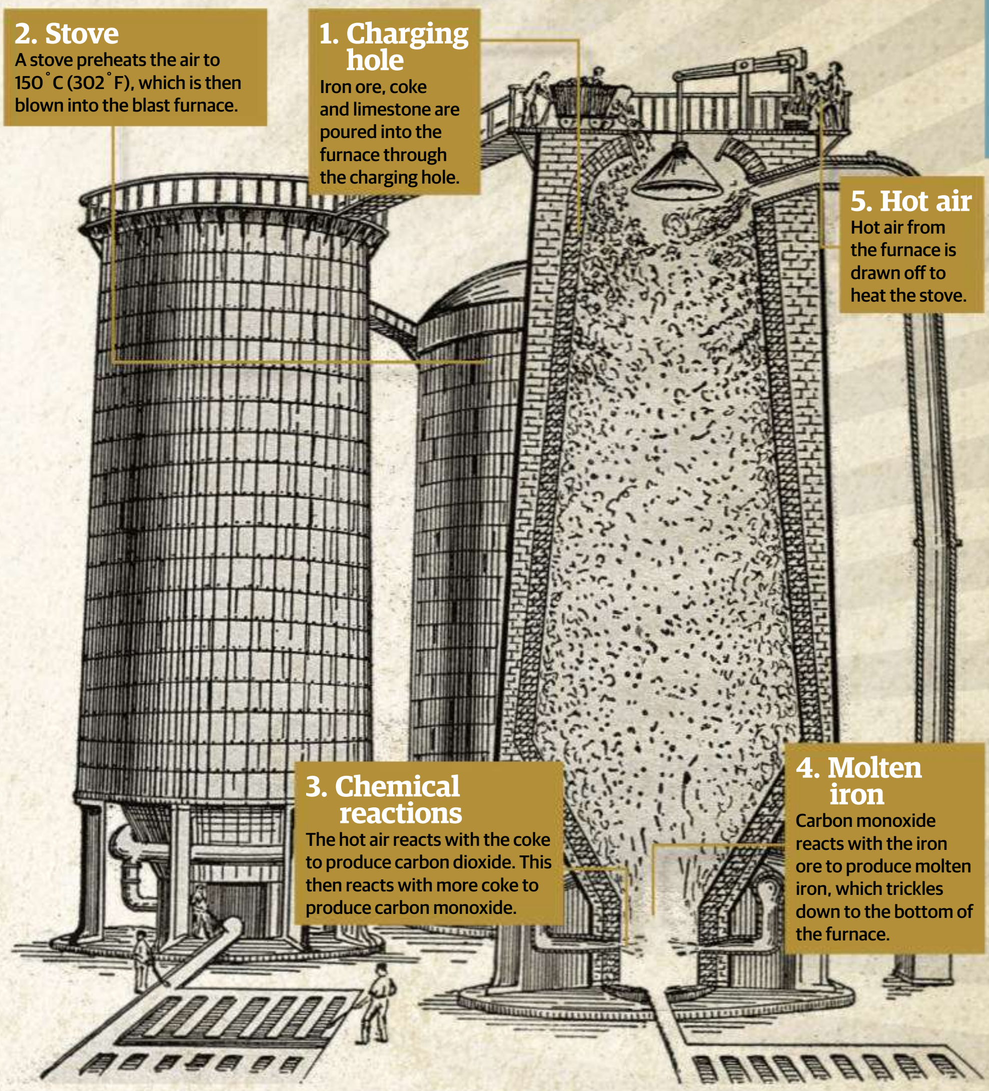
Among the new landmarks on this route were the Bristol Temple Meads railway station, the bridge over the river Saltash near Plymouth, and the tubular suspension and truss bridge over the Wye at Chepstow.



Talented from an early age, Brunel began studying geometry at the age of eight

THE HOT BLAST PROCESS

By preheating the air blown into a blast furnace, fuel consumption could be dramatically reduced and its output increased



1. Charging hole
Iron ore, coke and limestone are poured into the furnace through the charging hole.

2. Stove
A stove preheats the air to 150°C (302°F), which is then blown into the blast furnace.

3. Chemical reactions
The hot air reacts with the coke to produce carbon dioxide. This then reacts with more coke to produce carbon monoxide.

4. Molten iron
Carbon monoxide reacts with the iron ore to produce molten iron, which trickles down to the bottom of the furnace.

5. Hot air
Hot air from the furnace is drawn off to heat the stove.

> "BRUNEL WAS METICULOUS AND HANDS-ON, WANTING TO BE INVOLVED AT EVERY STEP"

In 1846, Parliament ruled in favour of the standard gauge, declaring that all trains outside of the South West were to be built without Brunel's design. Over time, lines that had been made with a broad gauge would have to be converted. By 1892, it had disappeared completely.

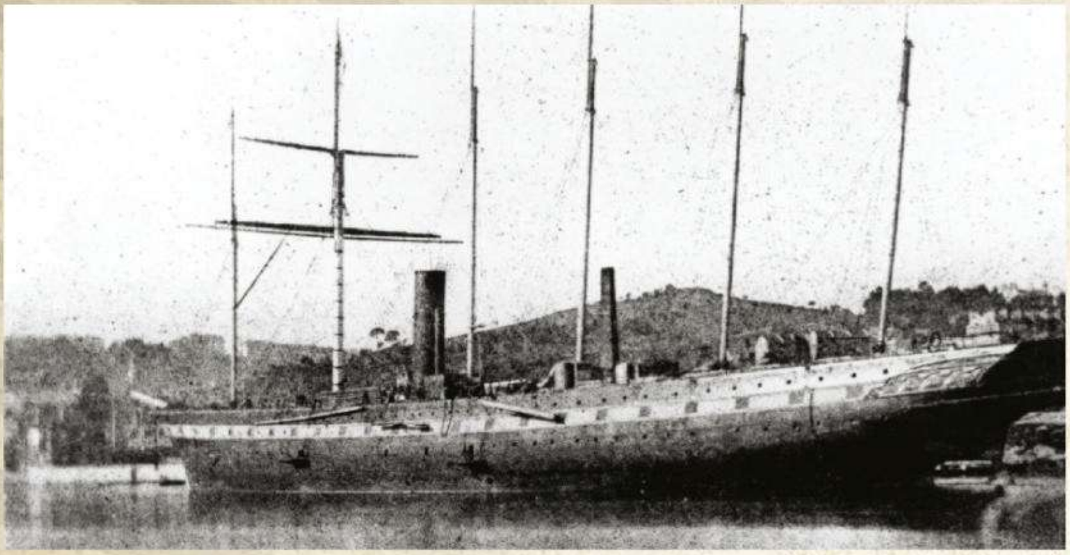
FURTHER INNOVATION

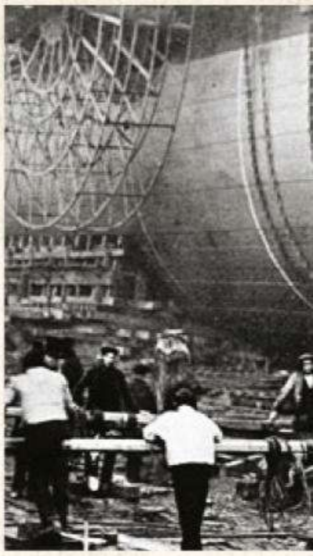
Despite its failure to revolutionise railway design, the Great Western Railway did revolutionise travel. It kick-started a new era of rail tourism, as Londoners flocked to the South West to enjoy its sandy beaches and slow-paced way of life. Upholstered seats, armrests and enclosed carriages soon became the norm, and cheap tickets were also offered, with excursion trains operating to popular destinations and events like the 1851 Great Exhibition. Railways were even built below ground, marking the birth of the world-famous London Underground.

By the end of the 19th century there was hardly a small town in Britain that did not have access to a train station. Fresh produce could be shipped across the country and newspapers could be printed in London and whisked up to Edinburgh the same day. The railways had opened up a whole new way of life, one that remains over a century on.

Though an improvement on the earlier wooden railway lines, wrought iron was not strong enough to support the heavier locomotives. It was possible to produce low-quality puddled steel, but the process was difficult to control and quality varied. To produce higher-quality steel involved a long and costly process. That was until 1856, when Henry Bessemer, an English inventor, patented a design for the first inexpensive process for the mass-production of steel. The key principle was the removal of impurities from iron by oxidation, with air being blown through the molten iron. The oxidation also raised the temperature of the iron mass and kept it molten.

With the introduction of the Bessemer process steel production boomed during the 1860s as railways could finally be made from steel at a competitive cost. Steel rails lasted more than ten-times



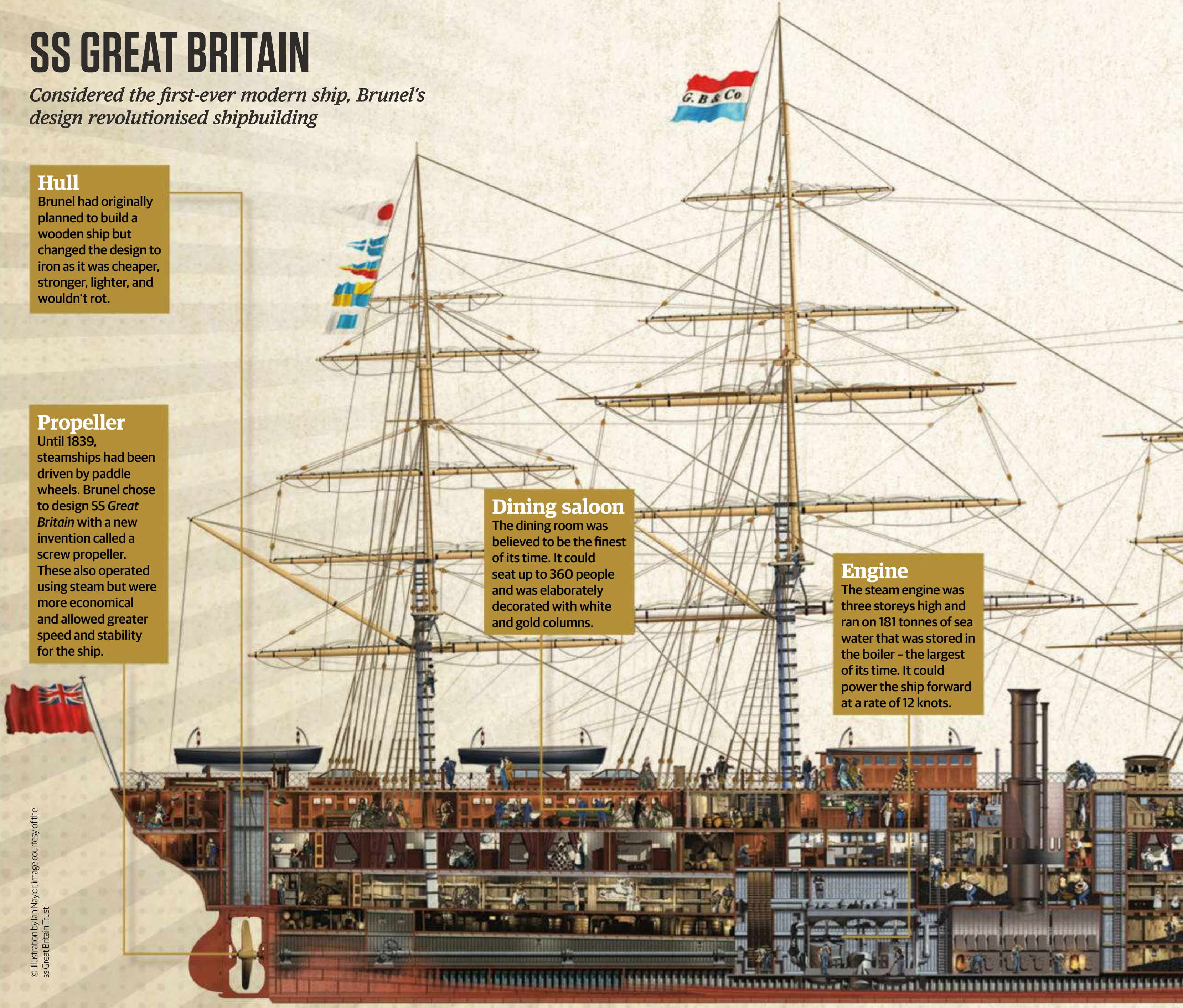


Captured in 1844, this image of SS *Great Britain* is believed to be the first taken of any ship

The launch of SS *Great Eastern* was constantly plagued with problems

SS GREAT BRITAIN

Considered the first-ever modern ship, Brunel's design revolutionised shipbuilding



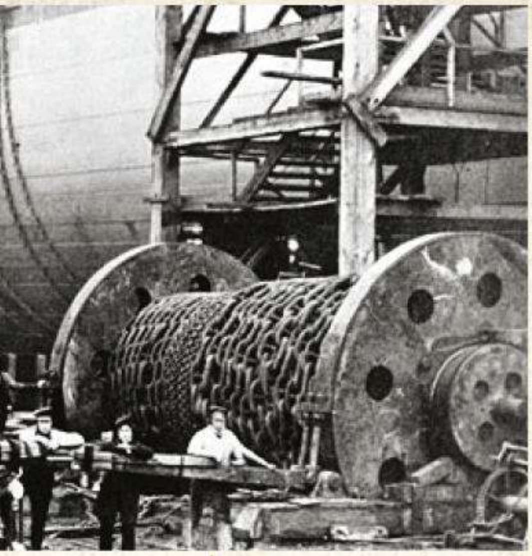
Hull
Brunel had originally planned to build a wooden ship but changed the design to iron as it was cheaper, stronger, lighter, and wouldn't rot.

Propeller
Until 1839, steamships had been driven by paddle wheels. Brunel chose to design SS *Great Britain* with a new invention called a screw propeller. These also operated using steam but were more economical and allowed greater speed and stability for the ship.

Dining saloon
The dining room was believed to be the finest of its time. It could seat up to 360 people and was elaborately decorated with white and gold columns.

Engine
The steam engine was three storeys high and ran on 181 tonnes of sea water that was stored in the boiler – the largest of its time. It could power the ship forward at a rate of 12 knots.

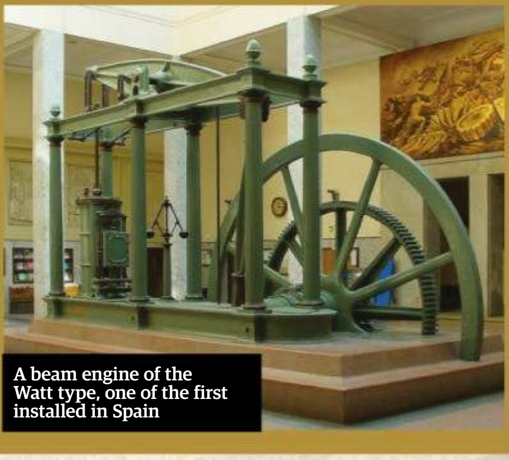
© Illustration by Ian Naylor, image courtesy of the ss Great Britain Trust



WATT'S STEAM ENGINE

Bringing steam to the masses allowed industries to upscale their operations

The Watt steam engine made two critical improvements to existing models. The first was the addition of a separate condenser cylinder alongside the main piston cylinder. This meant that the majority of condensation – and therefore vacuum creation – took place outside the heated drum. This allowed the main piston cylinder to remain at a temperature where water could quickly be pressurised. The second improvement was the introduction of an extra steam valve. The added valve increased the power of the engine as it capped and inserted low-pressure steam into the upper part of the main piston cylinder. This sped up vacuum creation, increasing the piston's downstroke power and, as a result, its actions per minute.



A beam engine of the Watt type, one of the first installed in Spain

"WITH ITS ADVANCED TECHNOLOGIES, BRITAIN WAS LEADING THE INTERNATIONAL TRADE MARKET"

longer than the iron rails used previously and allowed for the use of more powerful locomotives that could pull longer trains and longer railcars. Suddenly the productivity of the railroads rocketed. Rail became the dominant form of transport throughout the industrialised world.

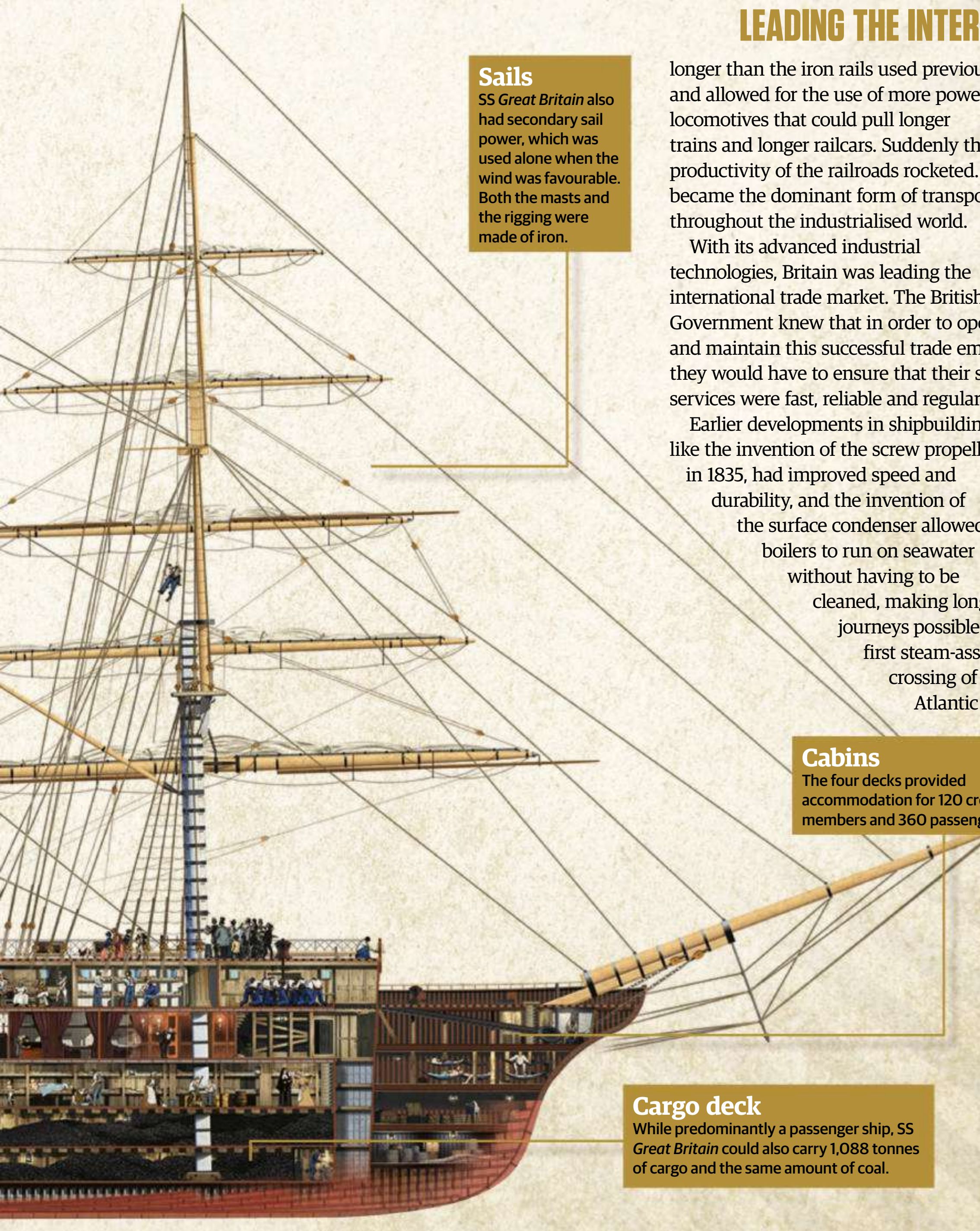
With its advanced industrial technologies, Britain was leading the international trade market. The British Government knew that in order to operate and maintain this successful trade empire they would have to ensure that their ship services were fast, reliable and regular.

Earlier developments in shipbuilding, like the invention of the screw propeller in 1835, had improved speed and durability, and the invention of the surface condenser allowed boilers to run on seawater without having to be cleaned, making long sea journeys possible. The first steam-assisted crossing of the Atlantic had taken place in 1819, when U.S. ship *Savannah* sailed from Georgia to Liverpool in 633 hours. Brunel, seeing the feats of engineering accomplished by his rivals, persuaded his directors that a transatlantic shipping line would be a natural extension to the services offered by their railway.

Determined to outdo the Americans one way or another, in 1837 Brunel launched SS *Great Western* – the longest ship in the world at 72 metres (236 feet) – which had been constructed in the Floating Harbour in the port of Bristol. Aside from a few early mishaps (including Brunel being injured during an engine-room fire), *Great Western* successfully made its maiden voyage to New York, although the ships' large size made frequent use of the Floating Harbour inconvenient, thus restricting it to the river near Avonmouth.

Six years later, SS *Great Britain* was launched. Designed for speed and comfort, it was considered the most revolutionary ship of the early Victorian period. It was made from metal rather than wood, powered by an engine rather than wind or oars, and driven by a propeller rather than paddle wheels. It was equipped with cabins and state rooms for 360 passengers and had the largest and most lavish dining room ever seen. But again the project was not to be without problems.

Brunel had been hired in 1832 to report on the deteriorating condition of Bristol's Floating Harbour, which he did, although the Dock Company – which owned the harbour – delayed acting on his suggestions. This indecision came to a head upon the completion of SS *Great Britain* in 1843, when it became clear that the ship was too wide to pass through the entrance lock. Brunel had



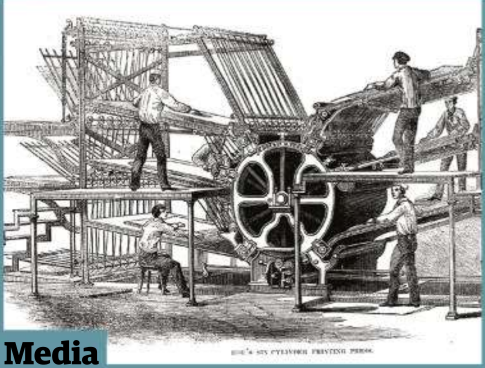
Sails
SS *Great Britain* also had secondary sail power, which was used alone when the wind was favourable. Both the masts and the rigging were made of iron.

Cabins
The four decks provided accommodation for 120 crew members and 360 passengers.

Cargo deck
While predominantly a passenger ship, SS *Great Britain* could also carry 1,088 tonnes of cargo and the same amount of coal.

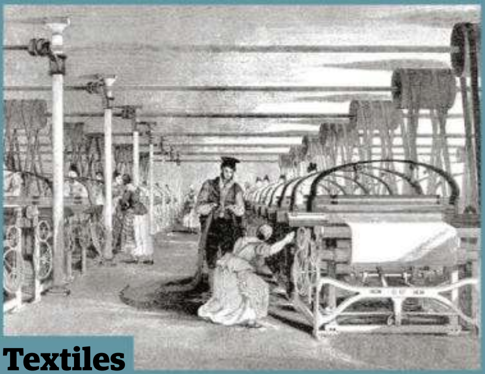
DEVELOPMENTS IN OTHER INDUSTRIES

With innovations in iron, steam-power and textiles, as well as electricity and steel, productivity soared in many industries



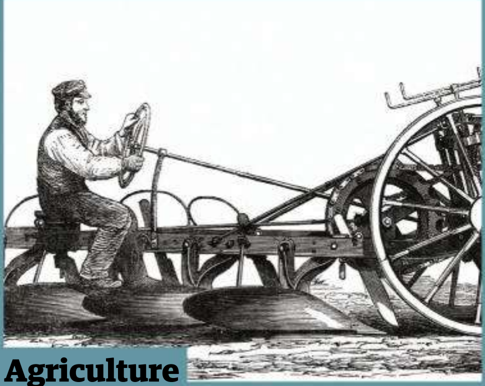
Media

Not only did the Industrial Revolution see the mass production of textiles and metals, it also signalled the start of the mass media. The invention of the steam-powered rotary printing press in 1843 allowed printers to create millions of copies of a page in a single day. Combined with the development of the railways, newspapers could now be printed and transported to thousands of destinations around the country, making news more accessible than ever.



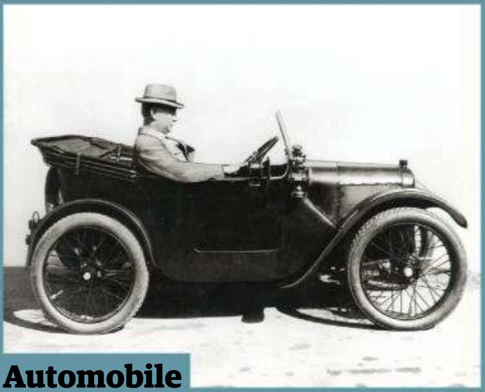
Textiles

The textile industry was at the centre of Britain's industrial expansion in the Victorian period. Technological advances meant that cottons, wools, silks and dyestuffs could be produced at unprecedented rates. By 1870, steam power in factories was the norm, and the invention of machinery like the semi-automatic Lancashire Loom and the self-acting mule meant that cotton could be spun in a fraction of the time it had taken a century earlier.



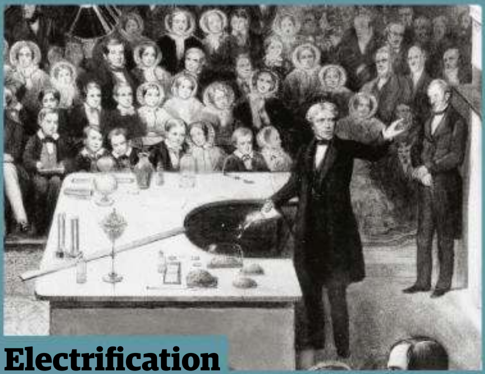
Agriculture

Though the Industrial Revolution saw a move away from traditional agriculture, it remained an important part of the British economy. In the decade following Victoria's accession, agriculture flourished as new crops were planted and artificial fertilisers started being used. However, the invention of reliable refrigeration technology towards the end of the 19th century meant that cheap meat could be imported from overseas, causing a drop in British sales.



Automobile

The world's first automobile was patented by Karl Benz in Germany in 1886. Two years later he began to sell his vehicles, making them the first commercially available cars. In the U.S., Henry Ford took advantage of the new assembly line process to run his own car manufacturing business. In Britain, Herbert Austin founded Wolseley Motors Limited, which was Britain's largest car manufacturer until Ford opened its doors in 1913.

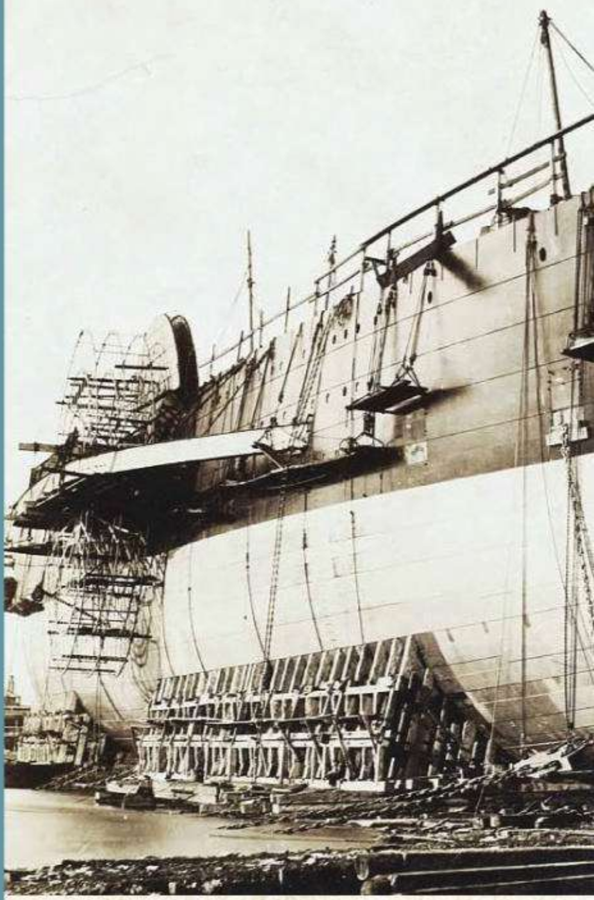


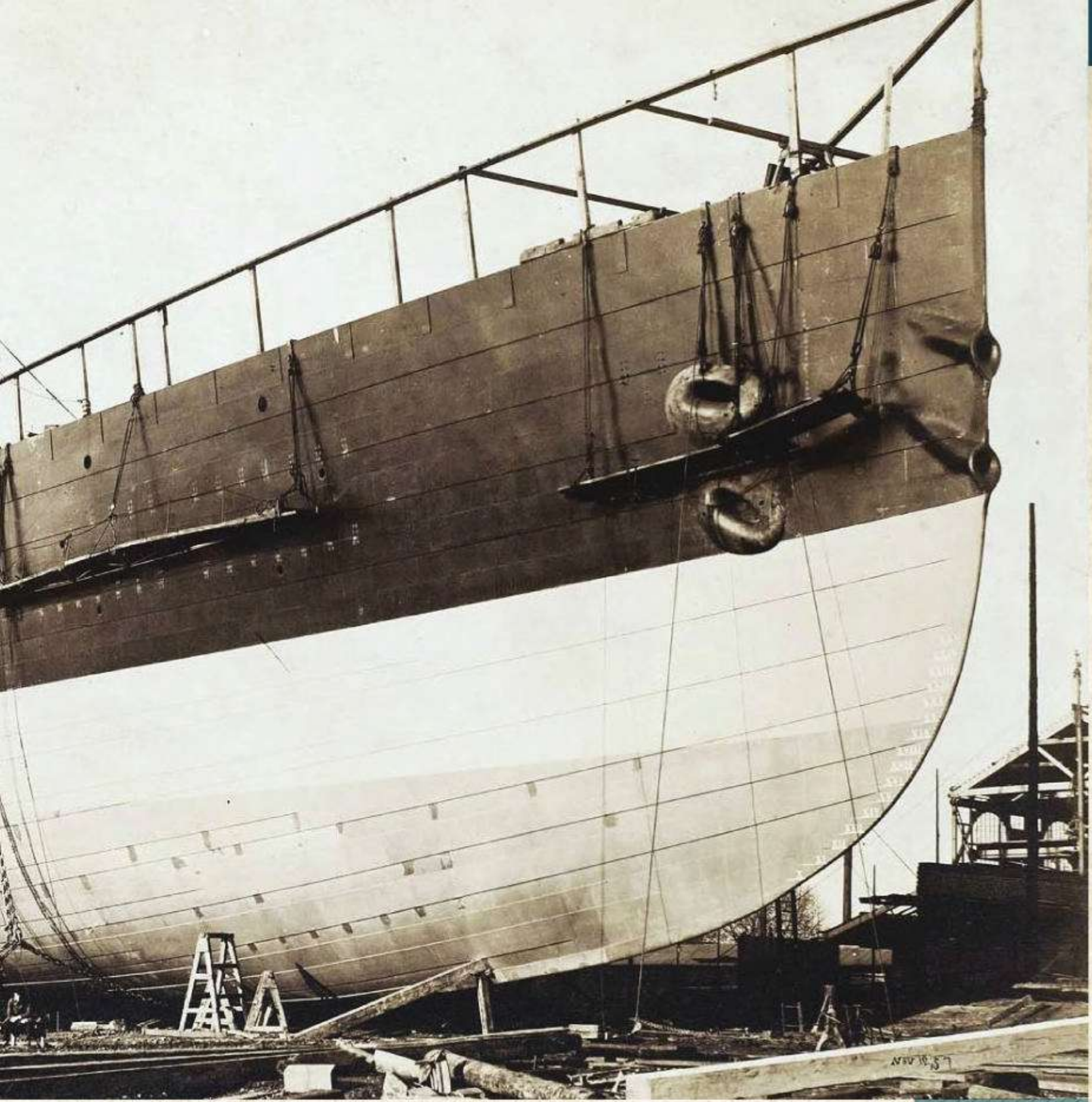
Electrification

Before Victoria's reign an electric current could only be produced using a battery. In 1831, Michael Faraday discovered electricity could be generated by moving a magnet over a wire, heralding the practical use of electricity. One of the most significant uses was for electric lighting in homes. In 1850, Joseph Swan began experimenting with carbonised paper filaments in a glass bulb. In 1880, he patented a design for the first incandescent light bulb.

Telecommunications

In 1837, Englishmen William Fothergill Cooke and Charles Wheatstone installed the first commercial telegraph system between Euston railway station and Camden Town. The system used electric current to move magnetic needles, transmitting messages in code. An undersea cable was built between England and France, and SS *Great Eastern* later laid down the first transatlantic cable. With transmitters in every post office, mass communication was now possible.





By far the largest ship ever built at the time of its 1858 launch, SS *Great Eastern*'s length would not be surpassed until 1899

Isambard Kingdom Brunel stands by the launching chains of the SS *Great Eastern*

anticipated that improvements to this area would have been made by this point, but his suggestions weren't acted on. Ultimately, masonry had to be removed from the side of the lock so that the ship could pass. It was never to return, as it was sold off after the Steamship Company was wound up in 1848. By 1853, it was operating a London to Australia service, which continued for almost 20 years.

In 1854, Brunel began to look even further afield. The SS *Great Eastern* was conceived as being able to make voyages to the likes of Australia and India and was unprecedented in its size. It was 210 metres (689 feet) long and capable of carrying 4,000 passengers. In his own words, he wanted "to make long voyages economically and speedily by steam, [which] required the vessel to be large enough to carry the coal for the entire voyage at least outwards, and unless the facility for obtaining coal was very great at the out port, then for the return voyage also." However, the construction process of the SS *Great Eastern* would prove to be an ordeal for Brunel. The project quickly ran over budget and overdue, and his relationship with shipbuilder John Scott Russell became strained. While Brunel was meticulous and hands-on, wanting to be involved at every step of the build, Russell was more laid-back, giving his workers instructions and then leaving them to get on with it. As the shipyard was under Russell's control, Brunel relied on his co-operation. When it became clear that this wasn't to be forthcoming he grew frustrated. Further adding to his problems, the first attempt to launch the ship on 3 November 1857 failed. It was successfully launched in 1858 and made its maiden voyage to New York in 1860 – which Brunel wouldn't live to see. Although it never fulfilled its original purpose of travelling to Australia, the vessel found use in laying transatlantic cables

THE IRON MAN'S LEGACY

Brunel's engineering vision and innovation made the building of large-scale, propeller-driven, all-metal steamships a practical reality, and between 1860–70 the shipbuilding industry soared. At Clydebank alone, more than 725,000 tonnes of iron ships were built. From the 1870s, steel replaced wrought-iron, resulting in the construction of lighter ships that could travel at much greater speeds. The Royal Navy were the first to take this brave new step into engineering, launching HMS *Iris* – the first all-steel ship in the Royal Navy – in 1877. Reaching speeds of more than 17 knots, it was the fastest ship the world had ever seen.

In addition to his work on travel infrastructure, Brunel worked in a number of other fields. He was responsible for the redesign and construction of various docks, such as Cardiff, Milford Haven and Monkwearmouth, and designed prefabricated hospitals to be shipped out to the Crimean War. He was elected a Fellow of the Royal Society in 1830, and in 1836 he married Mary Elizabeth Horsley, with whom he had three children: Isambard Brunel Junior, Henry Marc and Florence Mary.

Brunel died on 15 September 1859, ten days after suffering a stroke. His legacy lives on in the numerous landmarks and locations bearing his name and the travel network he left behind. A large proportion of the rail routes and bridges in the South West of England were a result of his drive to improve the country's infrastructure, a country he transformed forever.

IN HIS FATHER'S FOOTSTEPS

Much like how Isambard followed his father in choosing engineering as a career path, his second son, Henry Marc Brunel, also mimicked his father's lifestyle choice.

He took an interest in his father's work from an early age, even accompanying him on occasion: he was present when construction on the Tamar Bridge began and even acted as a runner during the launch of SS *Great Eastern*.

After attending private school at Harrow, Henry Marc attended King's College London from 1859–61, after which he took on a number of engineering apprenticeships before moving into the field full-time. Although his achievements never matched those of his father (in all fairness to him, how could they?), he still managed to leave his mark. His accomplishments included teaming up with fellow engineer Sir John Wolfe-Barry on a number of projects, including the Blackfriars Railway Bridge, Barry docks in Wales and Creagan Bridge in Scotland, not to mention the missionary and hospital boat the SS *Chauncy Maples*.

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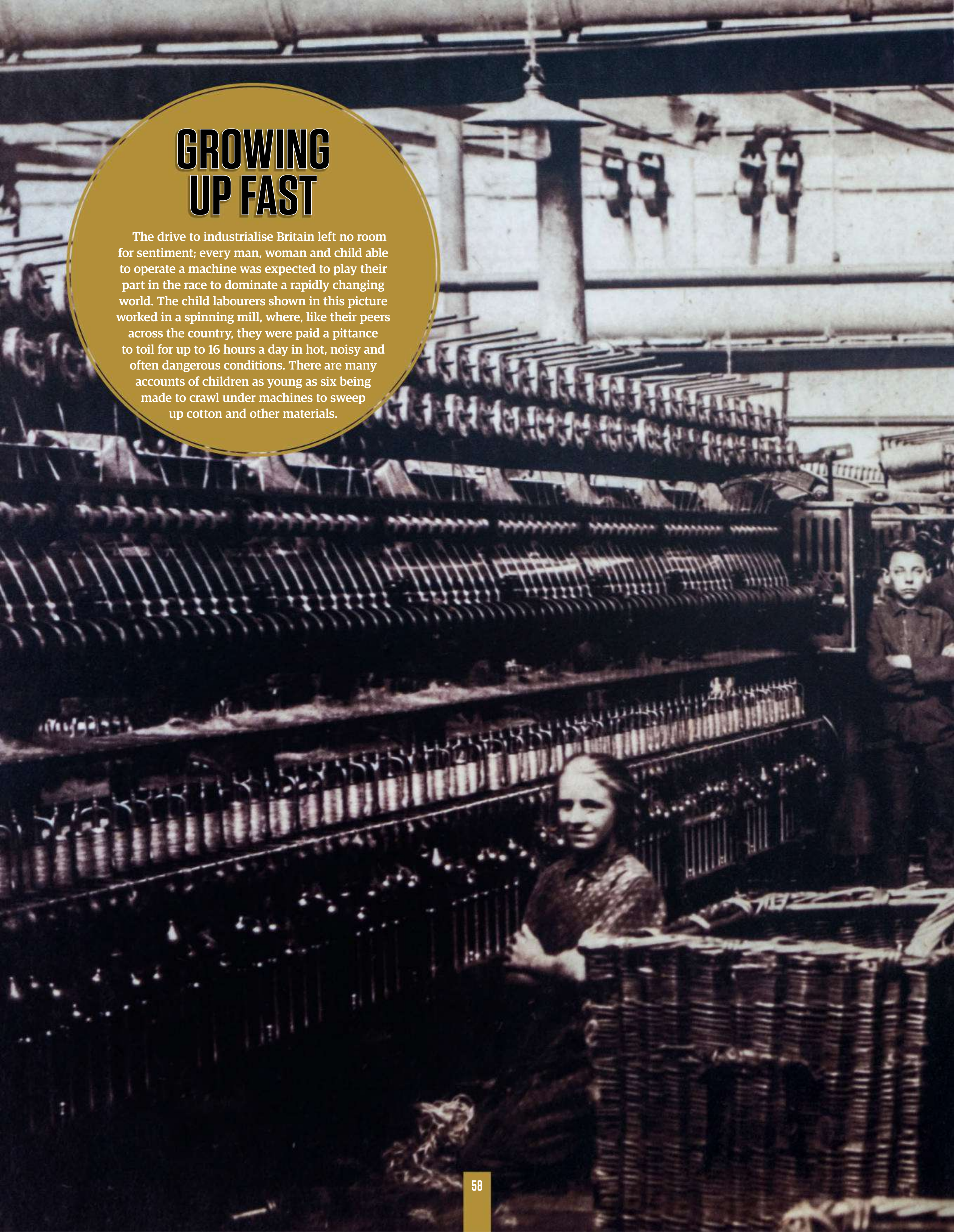
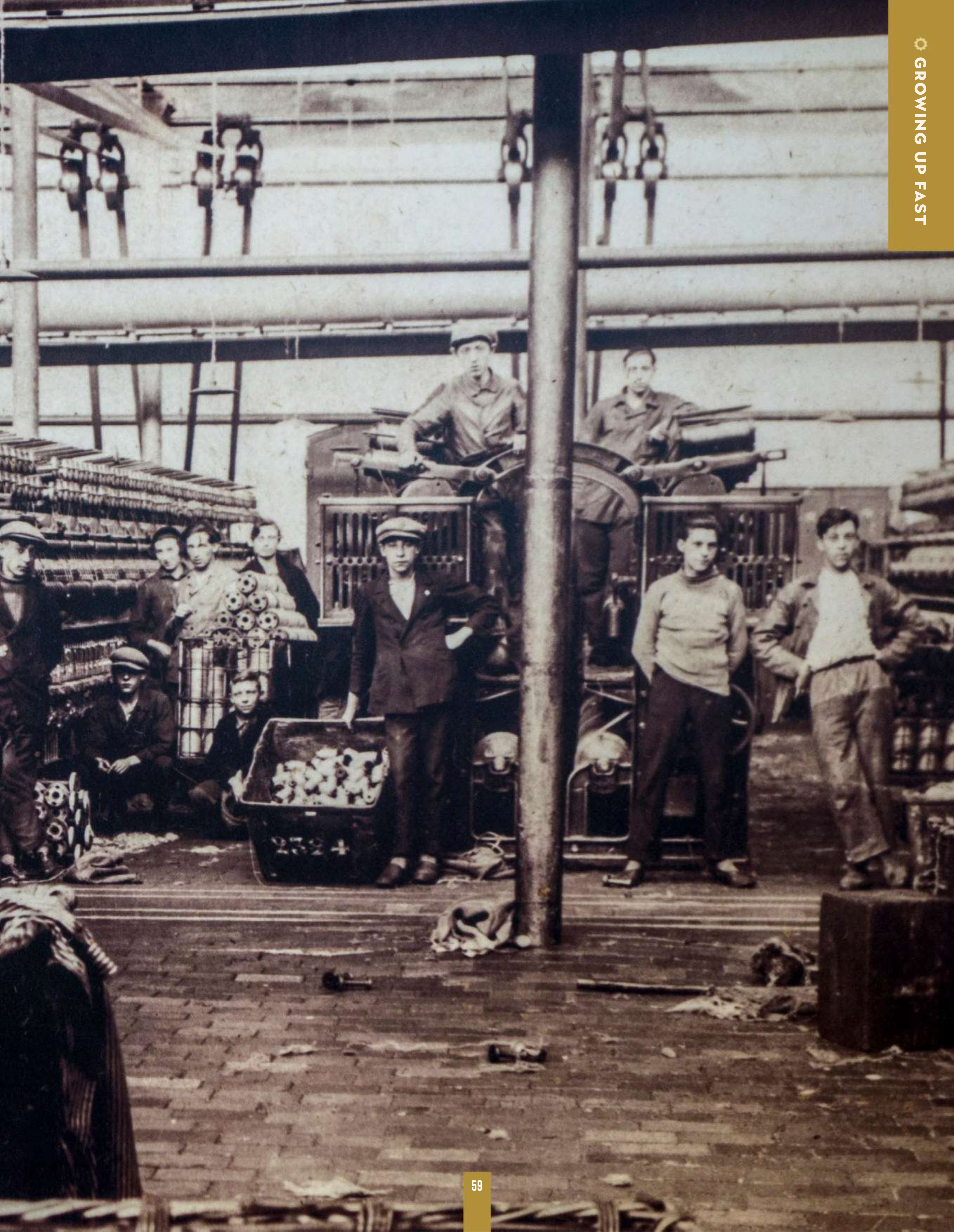


GROWING UP FAST

The drive to industrialise Britain left no room for sentiment; every man, woman and child able to operate a machine was expected to play their part in the race to dominate a rapidly changing world. The child labourers shown in this picture worked in a spinning mill, where, like their peers across the country, they were paid a pittance to toil for up to 16 hours a day in hot, noisy and often dangerous conditions. There are many accounts of children as young as six being made to crawl under machines to sweep up cotton and other materials.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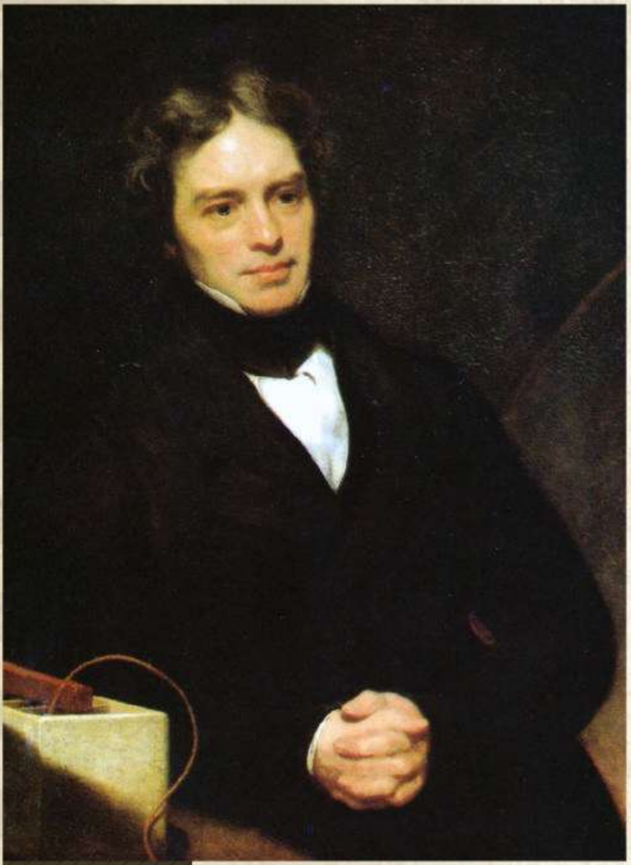
MICHAEL FARADAY

The scientist behind electromagnetic induction who played a key role in inspiring Einstein…



▲ Faraday was a chemist as well as a physicist; he investigated liquefied gases, optical glass and electrolysis

Michael Faraday was born in 1791 to a poor family who couldn't afford to educate him. Few could have guessed that he would go on to massively advance our understanding of electricity and more. He learned to read and write at Sunday school and became a bookbinder's apprentice in his teens.

Faraday loved to read and he worked his way through the books that he was binding, developing a keen interest in chemistry, electricity and magnetism. His newfound interest in science led him to attend a series of four lectures by chemist Humphry Davy, where he took extensive notes in the hope of securing employment at the Royal Institution. Eventually, his persistence paid off, and he managed to get a job working as a laboratory assistant to Professor Davy.

Faraday worked for Davy for several years, during which time the pair travelled to Europe. While with Davy, Faraday made several discoveries in the field of chemistry, including identification of the ring-shaped hydrocarbon benzene. He also made two new chemical compounds: hexachloroethane, which now forms the basis of military smoke grenades, and tetrachloroethylene, which is widely used to dry-clean clothes even to this day.

Faraday's major breakthroughs were not in chemistry, though, but in physics. In 1820, Hans Christian Oersted discovered that an electrical current could produce a magnetic field. Faraday was convinced that the opposite must also be true and began his most influential work on electromagnetic induction. His first discovery came shortly after, when he showed that by wrapping two insulated coils of wire around an iron ring a current could be transferred from one coil to another in a process that is known as mutual inductance.

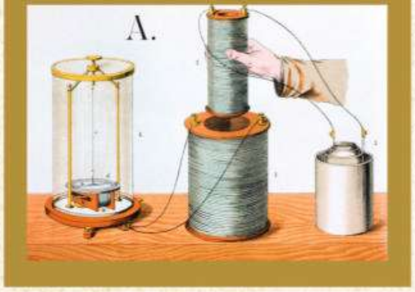
Keen to further this research, Faraday continued investigating the electromagnetic properties of materials, and this led to his greatest achievement of all in 1831 – the discovery of electromagnetic induction (see 'The big idea' for more information).

Faraday's work on electromagnetism sparked the interest of other scientists and mathematicians, which led to William Thomson writing to him suggesting that it was mathematically possible for magnets to alter the plane of polarised light. Faraday had been interested in this idea himself for a long time, conducting experiments to show how light and magnetic fields interact with each other. This was one of the first steps towards the realisation that visible light is actually electromagnetic radiation.

Later in life Faraday's health declined, but he continued to lecture at the Royal Institution. His scientific contributions were acknowledged by the royal family and, in 1858, Faraday moved to a home in Hampton Court, granted to him by Queen Victoria. He died in 1867, and, having previously refused a burial site at Westminster Abbey, he was buried in Highgate Cemetery.

THE BIG IDEA

Faraday was a prolific scientist, but he is best known for his work on electromagnetic induction. Faraday's Law states that a change in the magnetic environment near to a coil of wire will induce a voltage in the coil. Faraday developed a spinning copper disc that rotates next to a static magnetic field (provided by a bar magnet). As the disc spins through the magnetic field a potential difference is generated between the centre and the edge of the disc, creating a steady direct current. Faraday's disc was inefficient, but it provided the basis for the development of transformers, inductors, electrical motors and generators.



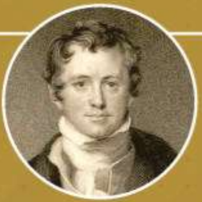
A LIFE'S WORK

We highlight some key events from Faraday's electrifying career in the 19th century

1791
Michael Faraday is born in Surrey, Britain, to James Faraday and Margaret Hastwell.

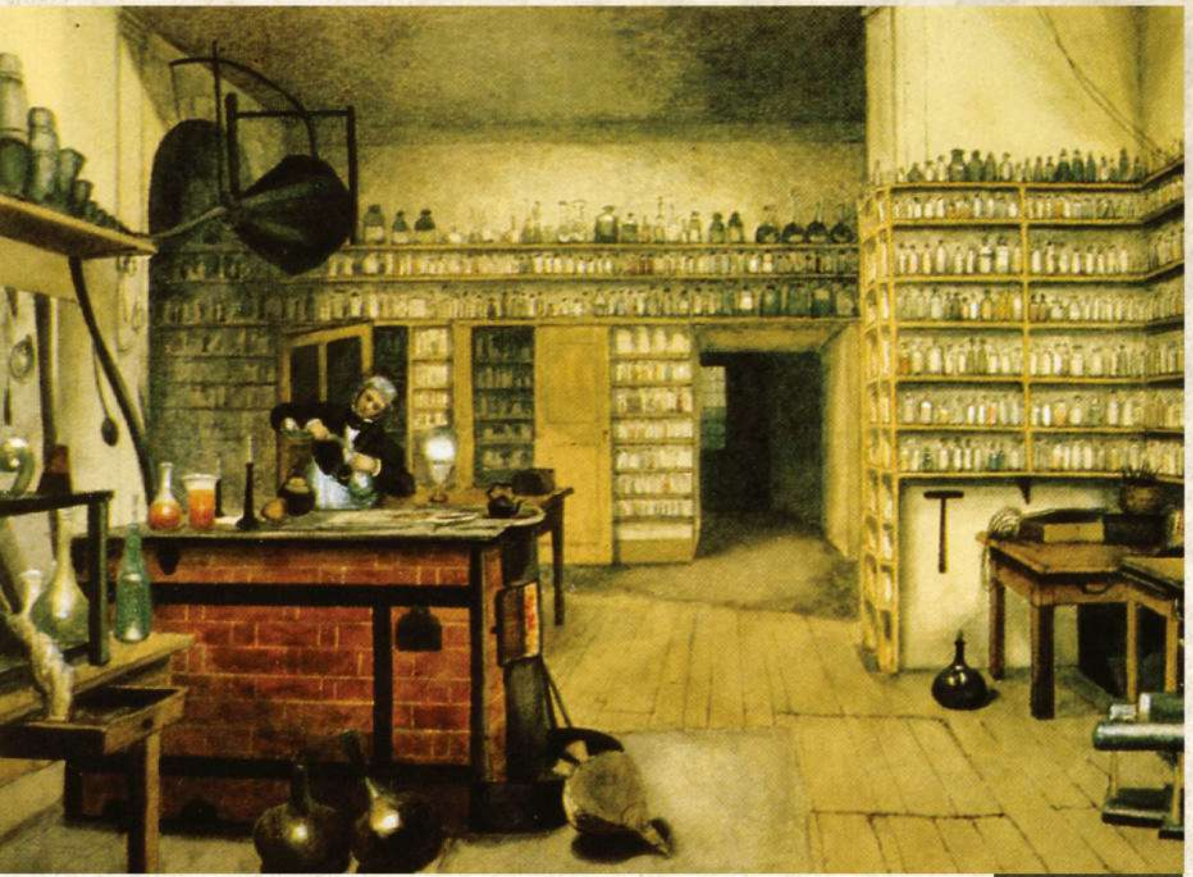
1805
Faraday starts work as a bookbinder's apprentice. During this time he develops an interest in science.

1813
He works as assistant to Professor Humphry Davy, making several advances in the field.



1821
Faraday discovers the principle behind the electric motor using the idea of electromagnetic rotation.

1824
He is elected a fellow of the Royal Society.



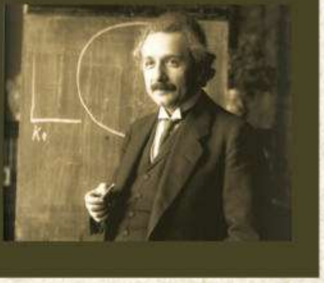
▲ Faraday worked at the Royal Institution in London, where he developed his theories in the fields of physics and chemistry

IN FARADAY'S FOOTSTEPS...

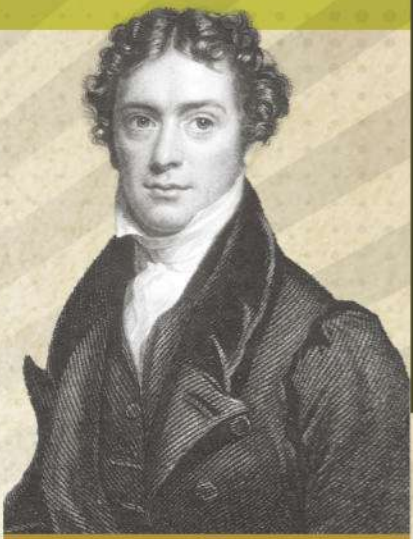
JAMES CLERK MAXWELL

James Clerk Maxwell was a Scottish physicist best known for his work on electricity, magnetism and optics. His theories on electromagnetism are underpinned by Faraday's experimental work. Maxwell attended many lectures at the Royal Institution and met Faraday on several occasions. He was more mathematically minded than his colleague and aimed to unify the existing work on electromagnetism, producing mathematical models to help explain the phenomena.

ALBERT EINSTEIN



The work of both Faraday and Maxwell inspired Einstein, and he kept pictures of both scientists on the wall of his study, alongside an image of Isaac Newton. Einstein's major work was to reconcile Newton's classical laws of physics with the new laws of electromagnetism, pioneered by scientists like Faraday. The work of Faraday and Maxwell provided an initial starting point for Einstein's game-changing special theory of relativity.



TOP 5 FACTS: MICHAEL FARADAY

1 NO ONE-TRICK PONY

Faraday developed an early version of the Bunsen burner and also discovered the laws of electrolysis.

2 NANOPARTICLES

Faraday was the first to report nanoparticles' properties, noticing that gold colloids (sub-micrometre-sized gold particles dispersed in a liquid) have different properties to solid gold.

3 MODEST MAN

He declined a knighthood offered by Queen Victoria and refused to accept presidency of the Royal Society twice.

4 CHRISTMAS LECTURES

Faraday founded the Royal Institution's (RI) Christmas Lectures. To this day, fun science demonstrations for children are broadcast every Christmas in Britain by the RI.

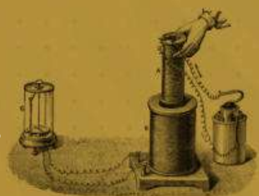
5 COMPETITION

Italian priest Francesco Zantedeschi and U.S. scientist Joseph Henry were working on electromagnetic induction too. Which man came up with the idea first is still contested.

© Corbis; Getty

1825
Faraday is appointed director of the laboratory at the Royal Institution, beginning the now famous Christmas Lectures.

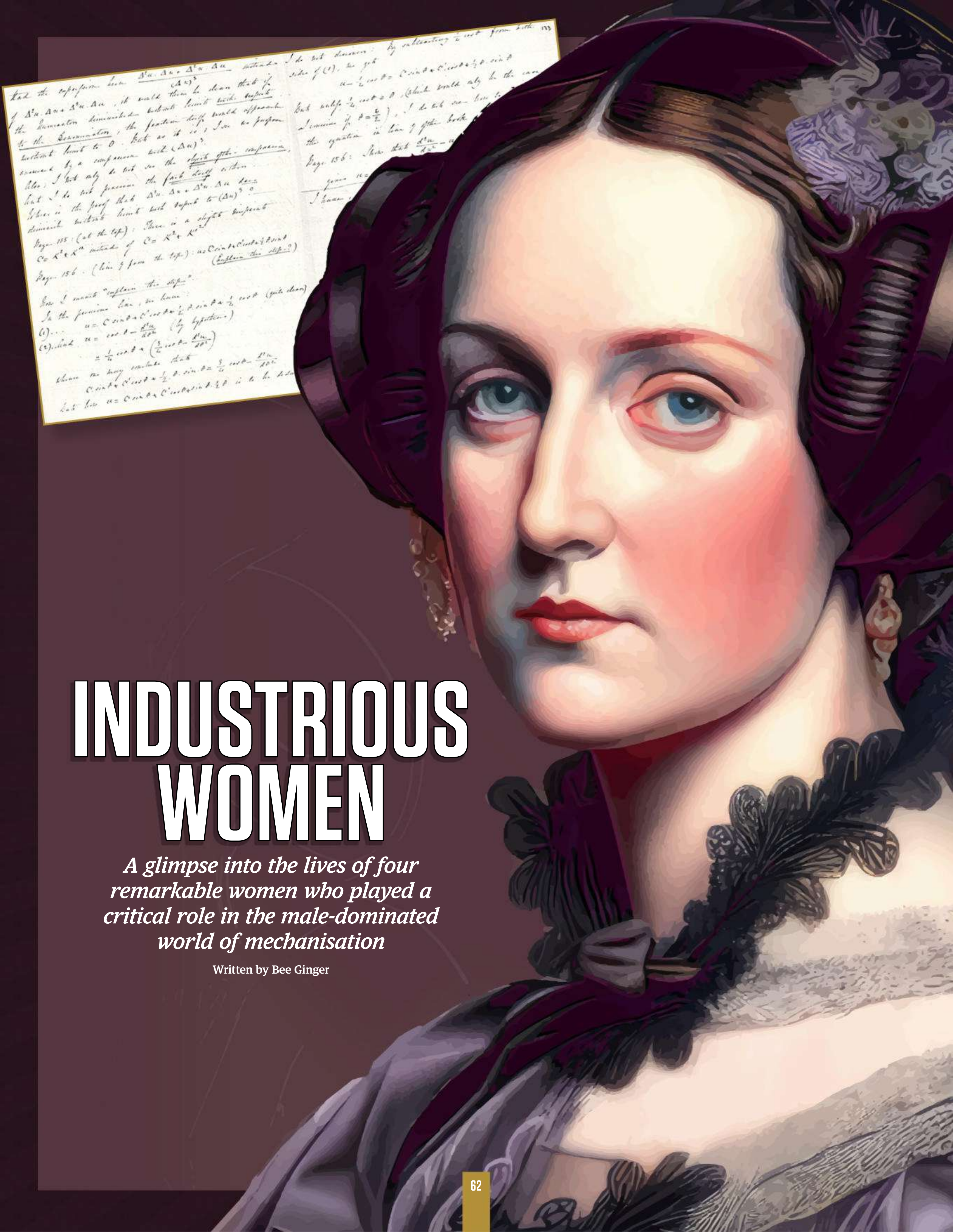
1831
He discovers the principle of electromagnetic induction and invents the electromagnetic generator.



1858
Faraday moves to Hampton Court, awarded to him by Queen Victoria for his services to science.

1867
Faraday dies aged 75 at his home in Hampton Court. He is buried in Highgate Cemetery.

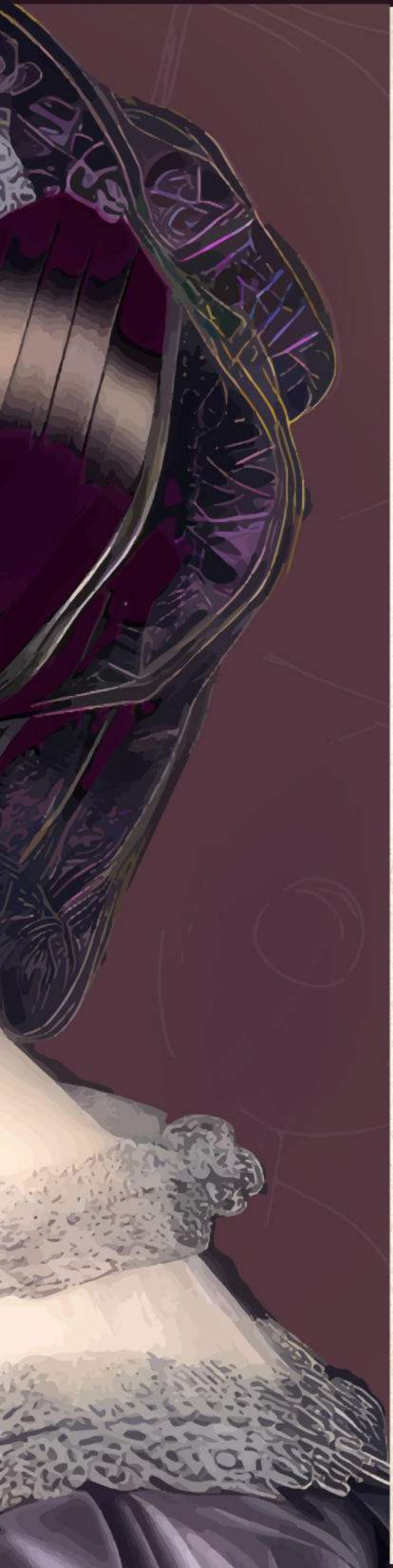
MICHAEL FARADAY
BORN 22 SEPTEMBER
1791
DIED 25 AUGUST
1867
SARAH HIS WIFE
BORN 7 JANUARY
1800
DIED 6 JANUARY
1879



INDUSTRIOUS WOMEN

A glimpse into the lives of four remarkable women who played a critical role in the male-dominated world of mechanisation

Written by Bee Ginger



Ada's mathematical mind has been rightfully honoured in more recent times

Ada married aristocrat William King-Noel at the age of 19. He was made 1st Earl of Lovelace in 1838, resulting in Ada's title becoming Lady Ada King, Countess of Lovelace

ADA LOVELACE

Despite being the daughter of English poet Lord George Gordon Byron, Ada was fortunately not raised by her erratic and abusive father but instead by her mother, who encouraged her love of mathematics, science and logic. From an early age Ada was fascinated with machines, spending hours pouring over scientific magazines, which at the time were filled with new inventions of the Industrial Revolution, and she often spent hours designing and drawing diagrams of magical flying machines and boats herself. At the tender age of 12, having studied the anatomy of birds, she wrote to her mother with an idea to create and construct a flying apparatus: "To make a thing in the form of a horse with a steam engine in the inside so contrived as to move an immense pair of wings, fixed on the outside of the horse, in such a manner as to carry it up into the air while a person sits on its back."

Unfortunately this fantastic idea never quite made it to fruition, however, other slightly safer concepts did. On being introduced to mathematician and inventor Charles Babbage at the age of 17, Ada quickly became his protégé, and the pair remained lifelong friends in part due to their somewhat unconventional personalities, with Babbage fondly referring to Ada as "the Enchantress of Numbers". Babbage was the Lucasian Professor of Mathematics at Cambridge and had attained great fame for his visionary plans to build a gigantic clockwork calculating machine. This was a complicated device he called the analytical engine, and it featured many similar elements to those now used in modern computers.

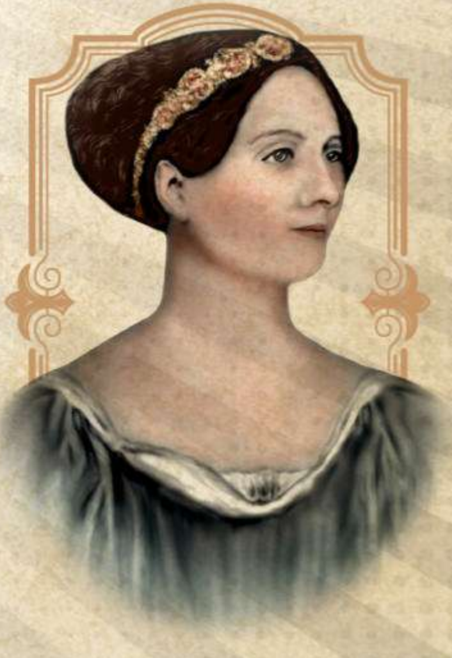
In 1842, Ada was asked to translate an article on the machine written by military engineer Luigi Menabrea into English. Ada did so, augmenting the article with enough of her own notes to make it three-times longer than the original. In the article (titled *Sketch of the Analytical Engine, with Notes from the Translator*) she wrote that it was possible to tailor the machine using a code in order to calculate Bernoulli numbers. These are a sequence of rational numbers considered by many to be the first algorithm, therefore making it the first computer program. These extra notes by Ada eventually went on to inspire the invaluable work of Alan Turing in the 1940s.

Ada believed content other than numerical calculations could be translated into digital form, including music. It is rumoured she also designed a program capable of predicting the results of horse races and used her talents for gambling. This unfortunately led to her having to pawn the family's jewels in secret when her bets backfired.

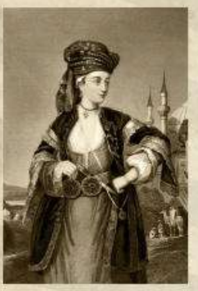
Despite her in-depth notes on Babbage's analytical engine gaining little traction at the time, when they were republished in B.V. Bowden's book *Faster Than Thought: A Symposium on Digital Computing Machines* in 1953 they were finally read and appreciated by a much wider audience.

The analytical engine remained a vision for Ada until her death from uterine cancer in 1852. Novelist and friend Charles Dickens visited her on her deathbed to read to her, neither of them ever imagining that one day the U.S. Department of Defense would honour Ada with a computer programming language used by the military. In fact, the Ada programming language continues to be deployed around the world in a number of real-time systems for transportation, aviation, space industries, health care, finance and infrastructure.

> **"ADA WAS FASCINATED WITH MACHINES, SPENDING HOURS POURING OVER MAGAZINES FILLED WITH NEW INVENTIONS"**



LADY MARY WORTLEY MONTAGU



Mary had to fight to educate herself, especially after the death of her supportive mother. Her father, Evelyn Pierrepont, 1st Duke of Kingston-upon-Hull, did not deem it his responsibility to educate his daughter

From a young age Mary Wortley was a keen scholar and eager to receive a better education than what was available to her at the time. Born into an aristocratic family and cursed with a despised governess, young Mary set about visiting her family's library in order to gain as much knowledge as possible. By the age of 16 she had not only taught herself Latin but had also written two books of poetry and a short novel.

Eloping at 23 to marry Edward Wortley Montagu, Mary, a now popular socialite, could be found hobnobbing in the court of King George I (and later the II). When he appointed her husband to the position of ambassador to the Ottoman Empire in 1716, Mary travelled with him to what was then known as Constantinople (Istanbul, Turkey). At the time smallpox was rife; Mary herself had contracted the disease and fully recovered from it. Sadly, her only brother was not so fortunate.

On discovering inoculation in the Ottoman Empire was widespread, Mary began to look closer into the procedure. She discovered that the smallpox virus would be introduced into an uninfected person by blowing smallpox scabs into their nostrils in a process known as variolation. Once they had recovered from the subsequent mild version of the virus they would be immune.

Mary began widely promoting this medical breakthrough, introducing the inoculation to Western Europe and Britain. She even had a surgeon from the British Embassy inoculate both her young children. Despite her efforts to publicise the benefits of inoculation, Mary was met with terrible hostility and even physical violence. Many deemed the procedure to be irreligious and Mary to be an ignorant and uninformed woman.

Lady Mary's embassy letters, written while in Constantinople, were published after her passing in 1762 and remain an important source of information for historians studying the period.

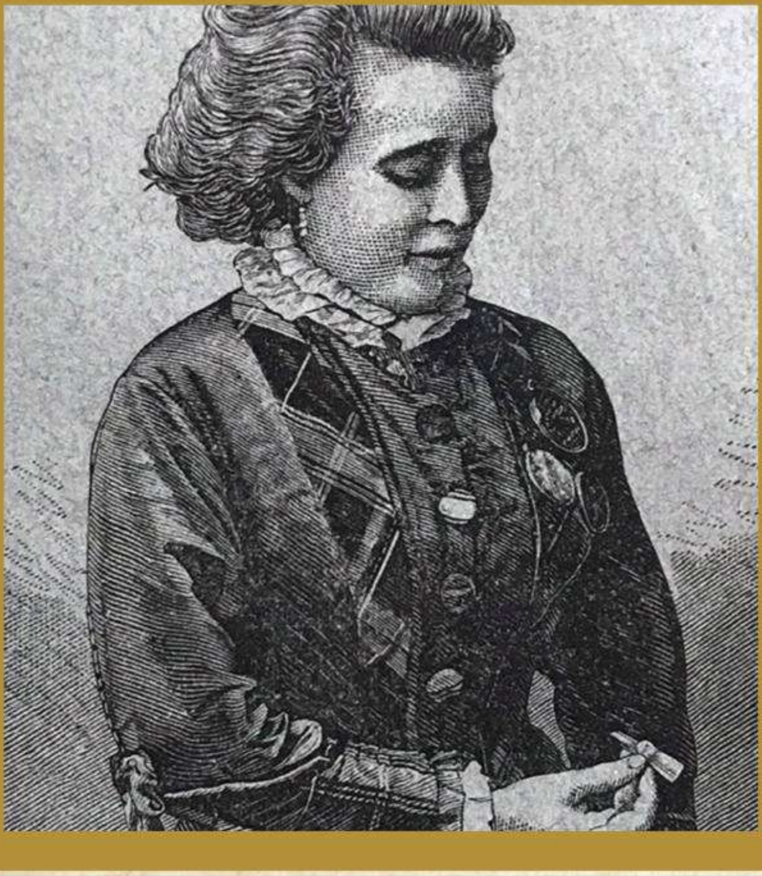
HENRIETTA VANSITTART

In a time where spousal or familial collaboration was often a key entry point into the workforce, it was difficult for women not only to be heard but also to stand apart from their male counterparts.

For Henrietta Vansittart, however, this was never going to hold her back. Self-trained, she took the practical skills and knowledge she learned from her father, James Lowe, a blacksmith-inventory and engineer who was working on ship propulsion, and struck out on her own with the intention of developing her ideas and processes in the field of engineering. She was actually incredibly successful and went on to achieve a number of great accomplishments. Following her father's death she made improvements on his works and designed the Lowe-Vansittart propeller, which was fitted on government ships and for which she was awarded a patent and a paper from the Association of Foreman Engineers and Draughtsmen. The propeller enabled ships to move more smoothly through the water, thus using less fuel and thereby reducing costs and speeding up voyages. HMS *Druid* and the RMS *Lusitania* were two of many ships that benefited from the propeller.

Henrietta's home was filled with the development models she had designed, built and tested, and in 1869 she took out a patent in America for her construction of screw propellers. She continued to improve the design of her propellers, giving them curved blades to enable greater efficiency.

Highly regarded by her fellow engineers and the Admiralty, she spoke and debated frequently about ship propulsion. She also published an informative pamphlet of her engineering works and today is considered to be one of the very first naval engineers of the 19th century.



Sadly, after being found wandering the streets of Newcastle in a confused state of mind and sent to the Tyne City Lunatic Asylum, Henrietta died in 1883 as a result of acute mania and anthrax

SARAH GUPPY

To describe Sarah Guppy as anything other than a trailblazer would be to do her a disservice. Despite being a woman in what was then a male-dominated society, she was a shining beacon revered by many of her peers, renowned for her somewhat eclectic work and endeavours as an engineer and inventor and most famously known for her hydraulic bridges. She was the first woman to gain a patent for a bridge, and her designs for the safe piling of bridge foundations caught the eye of none other than Scottish civil engineer Thomas Telford, who she shared the patent with for no money as she felt it was for the greater good. Telford went on to build his bridge over the Menai Strait in Wales. Isambard Kingdom Brunel followed suit some ten years later with the Clifton Suspension Bridge.

With the support of her machinist husband, Samuel (who she would divorce in 1830), Sarah constructed prototypes across a variety of different fields, designing a host of unique items from candlesticks that made candles burn for longer to coffee urns that could also boil eggs and warm toast, and beds that contained inbuilt fitness equipment – which doesn't sound very relaxing. She even devised a scheme to plant trees on railway embankments to prevent soil erosion. But it was her work with ships that gained her the most attention – and money. Her device to prevent caulking and barnacles from forming on the hulls of boats and ships reeled her in a contract from the British Navy and netted her a staggering £40,000 to provide them with her patent.

Sarah spent much of her life supporting worthy causes in public health, animal welfare and education, writing a book and opening a charity school for girls in addition to raising her six children. Unfortunately her success attracted the wrong kind of attention. At the age of 67 she married Richard Eyre-Coote, who was almost 30 years her junior. With pound signs before his eyes and a love of gambling, Eyre-Coote squandered Sarah's money, leaving her with little to her name.

In the first half of the 19th century, Sarah Guppy amassed an impressive ten patents, but as a woman she had to put these in her family name

> “SHE WAS REVERED BY MANY OF HER PEERS, RENOWNED FOR HER ENDEAVOURS AS AN ENGINEER AND HER HYDRAULIC BRIDGE”

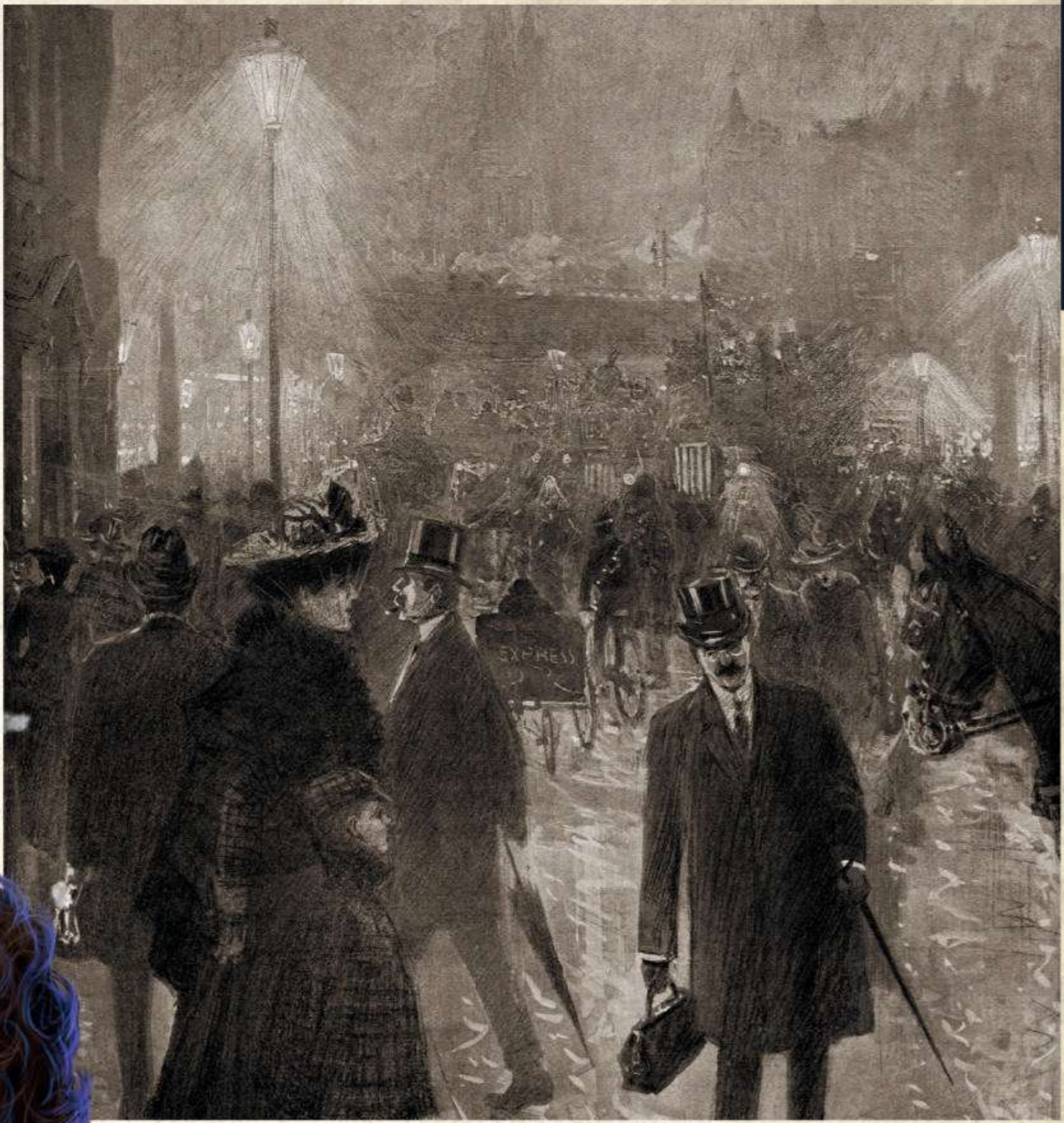
Her final act of graciousness came on her deathbed, where she bequeathed her tree-filled garden opposite her home to the city of Bristol with the condition that it not be built upon. The Bristolian public still enjoys this space today.

© Alamy, Getty

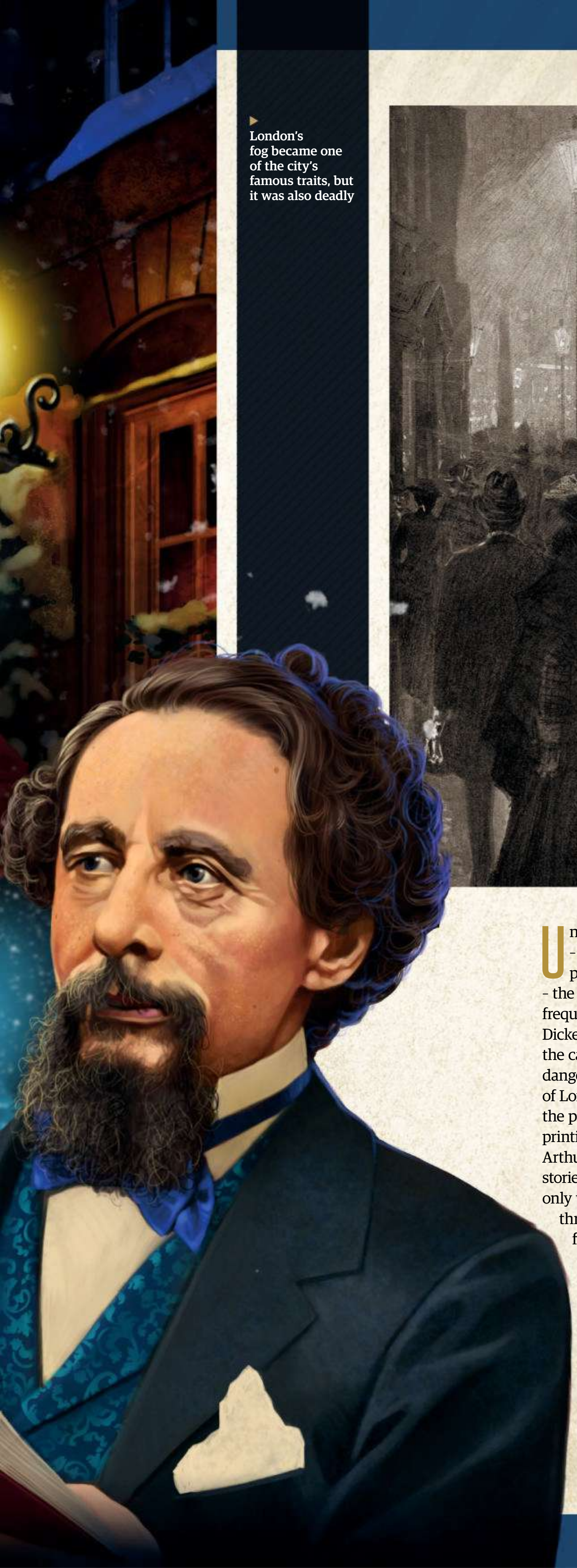
DICKENS' LONDON

Inside the real-life crime and grime that inspired literature's greatest novels

Written by Jeremy Black



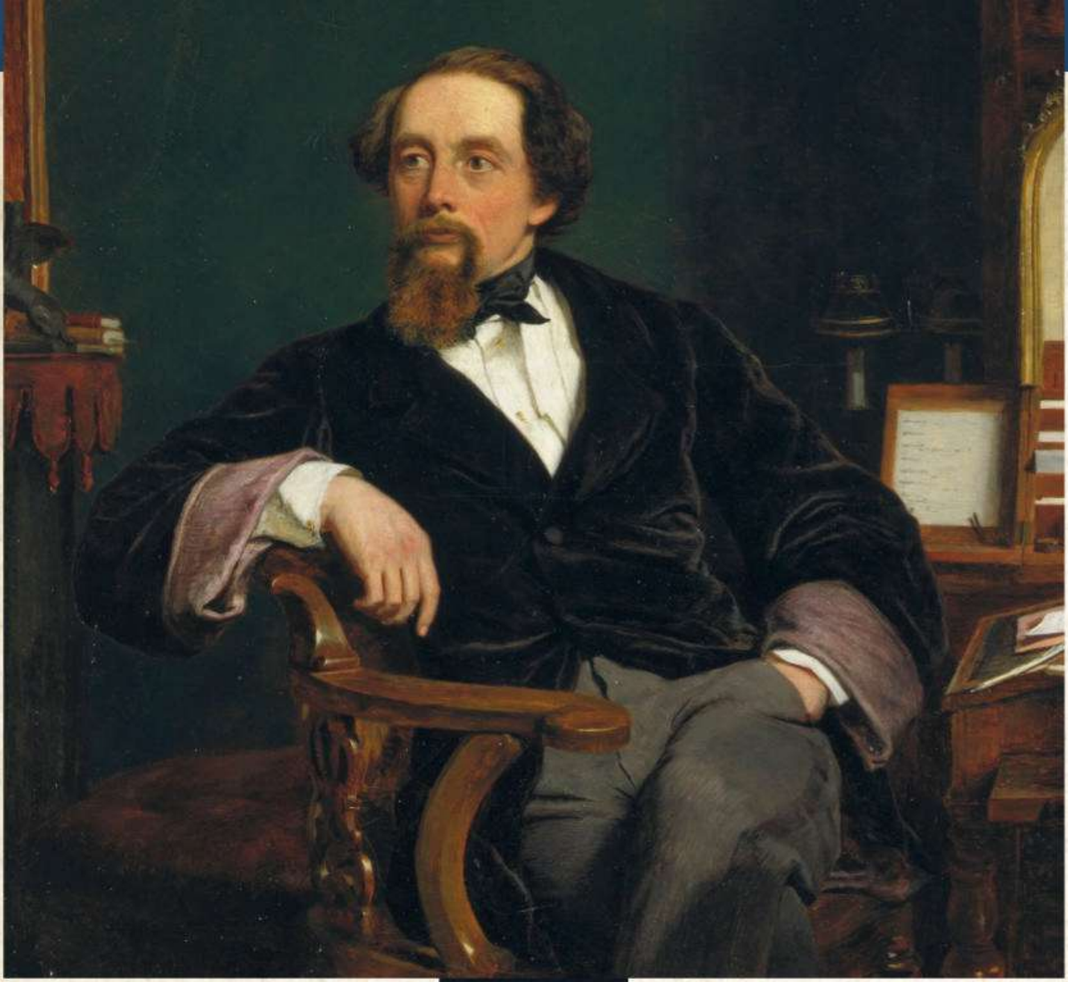
London's fog became one of the city's famous traits, but it was also deadly



Until the Carnaby Street of the 1960s – aside from images and experiences provided by war and royal occasions – the iconic images of London have frequently been Victorian. Charles Dickens and Jack the Ripper helped give the capital a reputation for squalor and danger that, despite being just one aspect of London, was a feature that gripped the popular imagination thanks to the printing press. The same can be said of Arthur Conan Doyle's Sherlock Holmes stories. These accounts circulated not only within the Anglosphere but also throughout the wider world, serving to further enhance London's somewhat grisly reputation.

As well as being the capital of the largest empire in the world it was the centre of many spheres of informal influence. Alongside the physical communications structure (notably the docks and railway stations) were the postal service and telegraphy that moved around ideas and literature.

London became a world city in the 19th century thanks to the growth of the empire and the metropolis itself, with its political, commercial and cultural power. This was further marked in London by triumphant monuments to its military heroes, notably in Trafalgar Square but also across central London. National greatness was also on display in new street names, although Dickens could be sceptical about this trend, as shown in his discussion of the Circumlocution Office in *Little Dorrit* and about both economic liberalism and reforming 'Chadwickism' in *Hard Times*. Dickens was also sardonic about MPs, as in *Nicholas Nickleby* with Gregsbury and his "tolerable command of sentences with no meaning in them… whether I look merely at home, or… contemplate the boundless prospect of conquest and possession – achieved by British perseverance and British valour – which is outspread before me, I clasp my hands, and turning my eyes to the broad expanse above my head, exclaim, 'Thank Heaven, I am a Briton!'"



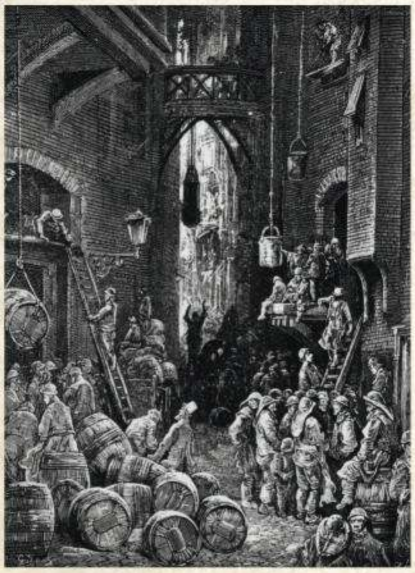
INDUSTRIAL HUB

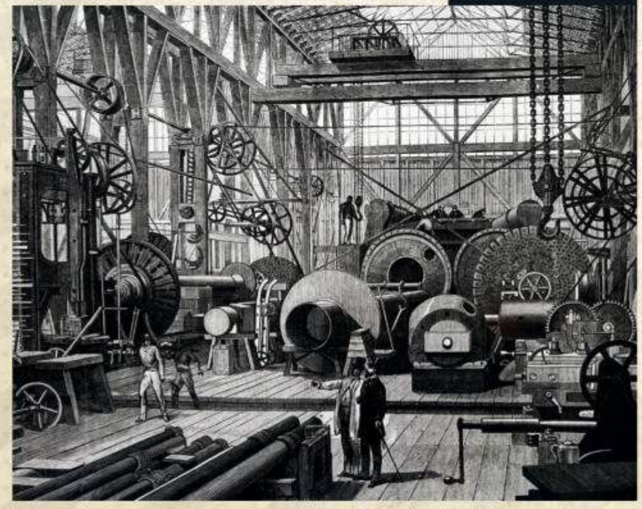
London in Dickens' lifetime was a centre of technological development, not least in manufacturing, although not on the scale of Coketown in *Hard Times*. Steam transformed many industries, including newspaper production. In 1814, *The Times* announced "the greatest improvement connected with printing since the discovery of the art itself" as it switched to a steam-powered press, allowing the production of 1,000 impressions an hour as opposed to the 250 per hour from an unmechanised hand-press. Prefiguring the move of *The Times* to new production facilities in Wapping in 1986, the machinery used in 1814 was secretly prepared to prevent the opposition of workers, who had already mounted a strike in 1810.

Dickens describes the spread of industry even up to the edges of the River Thames in *David Copperfield* as the titular character follows Martha Endell along the marshy banks of the river from Westminster south past "the great blank Prison" Millbank Penitentiary: "The clash and glare of sundry fiery Works upon the river-side, arose by night to disturb everything except the heavy and unbroken smoke that poured out of their chimneys."

Manufacturing continued to be important throughout the century, providing employment and profit that in turn fostered demand elsewhere in the economy. Although labour, rental and coal costs were relatively high, investment and working capital was available, as was Europe's largest consumer market, one of its leading ports and a range of skills. The presence of so much industry provided supply, demand, skill and the equivalent of an assembly line shared between enterprises. There were also skilled trades growing in the city, including the silk industry in Spitalfields and clock-makers in Clerkenwell. This concentration of activity proved beneficial for both the industrial and service sectors and contributed to the presence of specialised districts.

Another example of adaptability included the response late in the century to advances in retailing by means of the production of branded goods, which proved a way to provide scale in consumer-led industries.





▲ Dickens started his writing career as a journalist and published his first novel, *The Pickwick Papers*, in 1836

◀ Dickens often wrote about the poor working conditions that many Londoners endured

▼ The technological advances of the Industrial Revolution transformed London into the world's most powerful city

"LONDON IN DICKENS' LIFETIME WAS A CENTRE OF TECHNOLOGICAL DEVELOPMENT"

TRANSPORT FOR LONDON

London was also a centre of innovation in transportation, from the development of large-scale passenger train and omnibus services to the famous London Underground, the construction of which Dickens commented upon in *Dombey and Son* in 1848. He describes the disruption brought as Camden Town and nearby areas were transformed by the building of Euston, King's Cross and St. Pancras stations and their extensive marshalling yards and lines:

"The first shock of a great earthquake had… rent the whole neighbourhood to its centre… Houses were knocked down; streets broken through and stopped… Everywhere were bridges that led nowhere… mounds of ashes blocked up rights of way, and wholly changed the law and custom of the neighbourhood… the yet unfinished and unopened Railroad was in progress, and, from the very core of all this dire disorder, trailed smoothly away, upon its mighty course of civilisation and improvement."

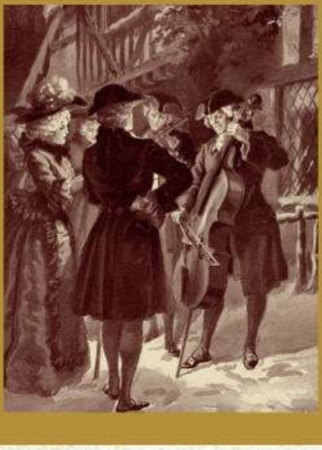
When MP Robert Lowe spoke at the lunch served at Farringdon station on 9 January 1863 to mark the opening of tube services, he also reflected on the advances that the new rail system brought to London. "The traffic of London has long been a reproach of the most civilised nation of the world, and the opprobrium

A VERY DICKENS CHRISTMAS

Some classic seasonal traditions introduced by the Victorians

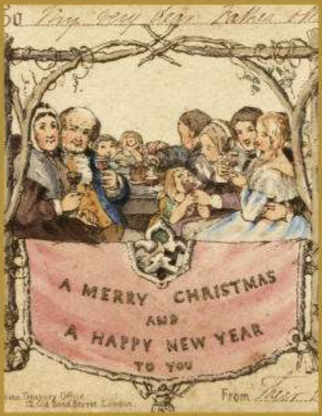
CAROLS

Carolling had been around for quite a while, but the puritan era had seen the practice lose popularity. The Victorian period saw a revival, though, as musical entertainment became more common and publicly available. The first major collection of Christmas carols was published in 1833.



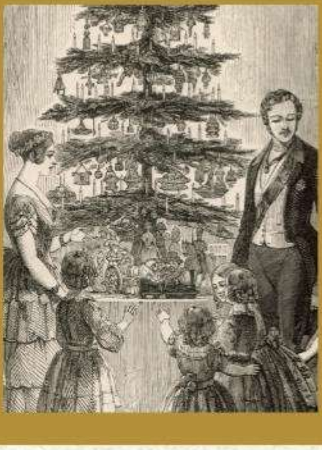
CARDS

The first known Christmas card was illustrated by J.C. Horsley and commissioned by Sir Henry Cole, the first director of the Victorian & Albert Museum, in 1843. Costing one shilling, it was far too expensive for most families, but by 1880, thanks to cheaper production, it had become a massive industry.



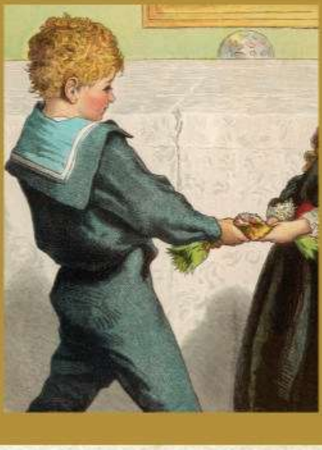
TREE

Decorating a tree for Christmas was common in Germany and something Prince Albert brought with him to Britain as a tradition in Queen Victoria's household. The concept gained popularity when an image of the royal family decorating a tree appeared in *The Illustrated London News* in 1848.

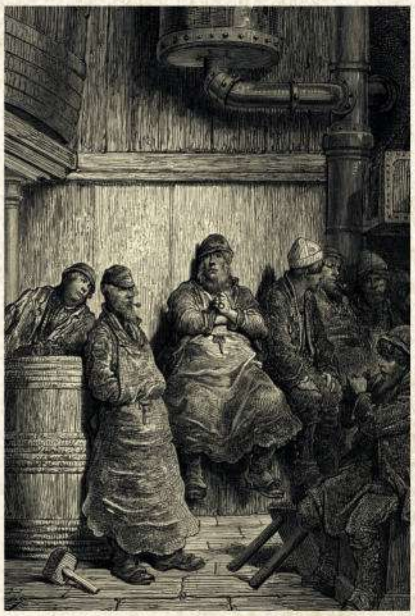


CRACKERS

Inspired by the way sweets were wrapped in Paris, in 1848 confectioner Tom Smith brought the idea to Britain. A package was filled with sweets, wrapped in paper and would snap when pulled apart. The 'banger' was added in the 1860s, and small gifts replaced sweets a little later on.



of the age," he said. "Dr [Samuel] Johnson used to say that if you wanted to see the full tide of human life, you must go to Charing Cross, but Dr Johnson would have to raise his estimation of the full tide, or rather of the close jam of the full tide of human life, many hundred per cent before he could arrive at the state which the traffic of London has now reached… Through gas-pipes and water-pipes and sewers… and… the Fleet Ditch… The line has had to worm its way through a complicated and intricate labyrinth under difficulties almost insuperable."



London brewery workers depicted by Gustave Doré, who captured the oppressive atmosphere of the city

Steam power made the headlines, but London's market was already the cause and beneficiary of major improvements prior to that, both in shipping services and improvements to the roads. The efficiency of road freight rose in particular with the cutting of journey times through night-time running, which became more significant in the early 19th century, a period that also saw road improvements that made such journeys far less perilous.

The docks, where new immigrants to the country arrived, were a dramatic demonstration of London's global sway and one that became steadily more impressive during the century, with no other place in the world matching London's capability. It was also a major centre of employment as, more generally, was the commercial world. Thus, in the early 19th century, the largest warehouse labour force in London was that of the East India Company, with over 3,000 permanent labourers at its peak.

WORK AND POVERTY

As a whole, however, dock labour was casual, which increased the strains on income and life. Unskilled labour suffered in particular. Alongside the hardness captured in *Our Mutual Friend*, in which the river yields coal, wood, a basket used to shelter a baby, and bodies for scavengers, there was also perpetual tension over discipline and pilfering. Dockland was very different to Whitehall or the City, but it was equally important. It was also more multicultural than any other part of London. It was in Shadwell that Dickens visited an opium den to gain material for the dramatic opening scene in *Edwin Drood*.

Dockland was also a centre for social unrest and confrontations between labourers and the authorities. The aftermath of one such confrontation was reported by *Bell's Weekly Messenger* on 13 August 1853: "On Wednesday, Mr Yardley, the magistrate at the Thames Police-court, was engaged for several hours in the investigation of charges of assaulting, wounding, and using threatening language, preferred against dock labourers, connected with the late strike for an increase of wages. The persons charged were, with one exception, Irishmen; and some of the assaults proved to have been committed by them were of the most savage description."

KEY DICKENS LOCATIONS

Some of his most-mentioned locations in the capital

HOLBORN

FEATURED IN: 9 BOOKS

Many of Dickens' stories pass through Holborn in some manner, which makes sense since it was a region on the edge of the city centre, hosted newspaper offices and was where he lived for many years.

COVENT GARDEN MARKET

FEATURED IN: 9 BOOKS

In Dickens' time Covent Garden was one of the most vibrant and visited shopping areas of London, and it remains a cultural hotspot of the city to this day. It was also a great mixing place for people of different social classes.

OLD BAILEY

FEATURED IN: 9 BOOKS

Having worked as a court reporter from 1829 to 1833, Dickens would have been very familiar with the cases and procedures of the Central Criminal Court and Newgate Prison that sat on Old Bailey Street in central London.

THE STRAND

FEATURED IN: 11 BOOKS

This remains one of the most iconic streets in London, stretching from Fleet Street (the hub of newspapers) to Charing Cross (the commercial centre of the city). It's a region Dickens would have frequented often.

TEMPLE

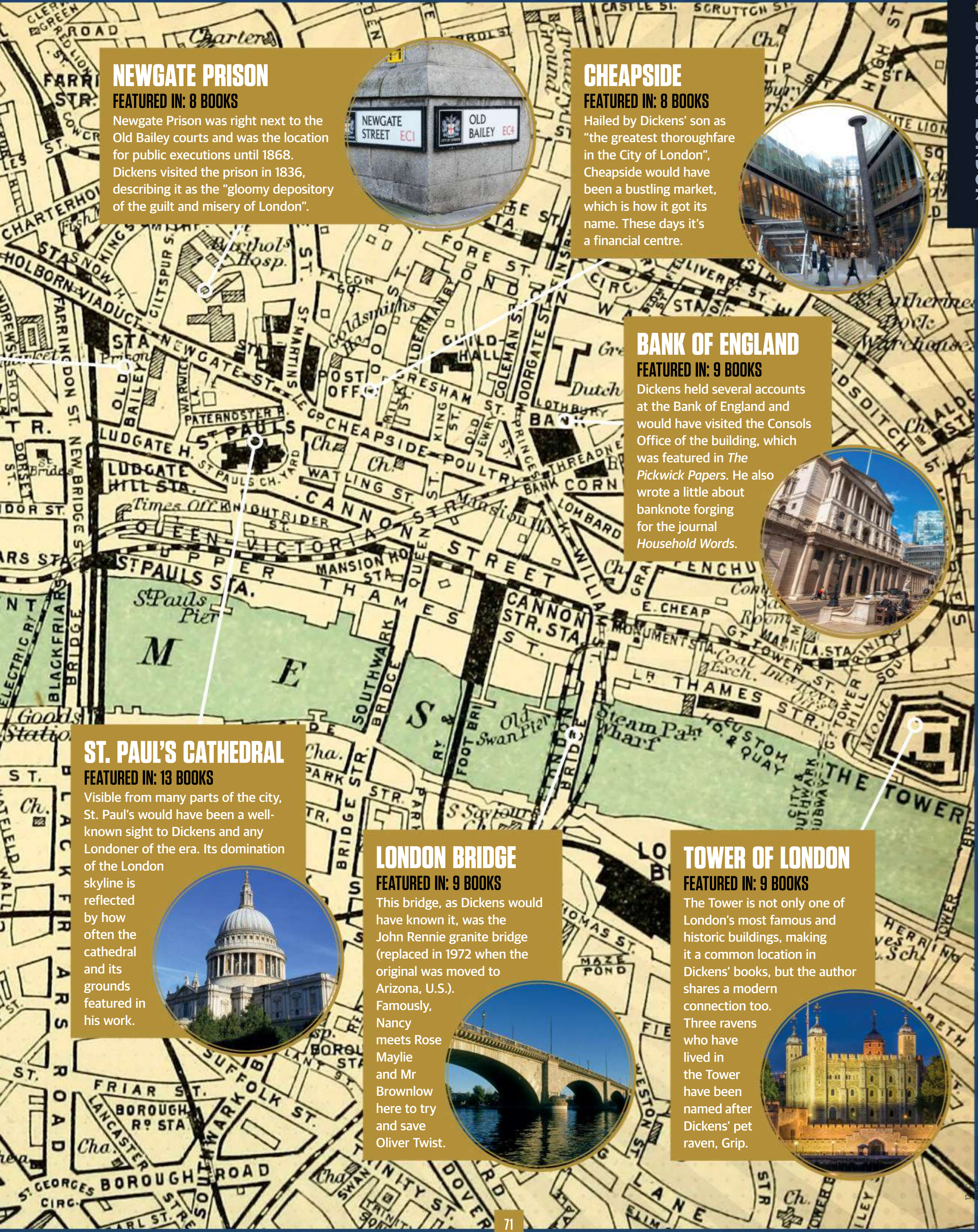
FEATURED IN: 9 BOOKS

The Temple was and continues to be the heart of the legal profession in London. It was a common location for Dickens to send his characters who were having legal difficulties or who worked as a barrister themselves.

PALACE OF WESTMINSTER

FEATURED IN: 14 BOOKS

That this should be the location that appears most in Dickens' work is somewhat surprising, but then he spent a good amount of time in the Palace of Westminster when he was honing his craft as a journalist for *The Mirror of Parliament*.


NEWGATE STREET EC1
OLD BAILEY EC4
HOLBORN VIADUCT
NEWGATE ST.
OLD BAILEY
ST. PAULS
LUDGATE HILL STA.
CHEAPSIDE
POULTRY
GRESHAM ST.
GUILD HALL
MOORGATE ST.
BANK
THREADNEEDLE
CORNHILL
LOMBARD
CANNON STREET
QUEEN VICTORIA ST.
UPPER THAMES ST.
MANSION HO. STA.
CANNON STR. STA.
MONUMENT STA.
LR THAMES STR.
CUSTOM QUAY
SOUTHWARK BRIDGE
LONDON BRIDGE
BLACKFRIARS BRIDGE
ST. PAULS STA.
THE TOWER
BOROUGH RD STA.
BOROUGH ROAD

NEWGATE PRISON

FEATURED IN: 8 BOOKS

Newgate Prison was right next to the Old Bailey courts and was the location for public executions until 1868. Dickens visited the prison in 1836, describing it as the "gloomy depository of the guilt and misery of London".

CHEAPSIDE

FEATURED IN: 8 BOOKS

Hailed by Dickens' son as "the greatest thoroughfare in the City of London", Cheapside would have been a bustling market, which is how it got its name. These days it's a financial centre.

BANK OF ENGLAND

FEATURED IN: 9 BOOKS

Dickens held several accounts at the Bank of England and would have visited the Consols Office of the building, which was featured in *The Pickwick Papers*. He also wrote a little about banknote forging for the journal *Household Words*.

ST. PAUL'S CATHEDRAL

FEATURED IN: 13 BOOKS

Visible from many parts of the city, St. Paul's would have been a well-known sight to Dickens and any Londoner of the era. Its domination of the London skyline is reflected by how often the cathedral and its grounds featured in his work.

LONDON BRIDGE

FEATURED IN: 9 BOOKS

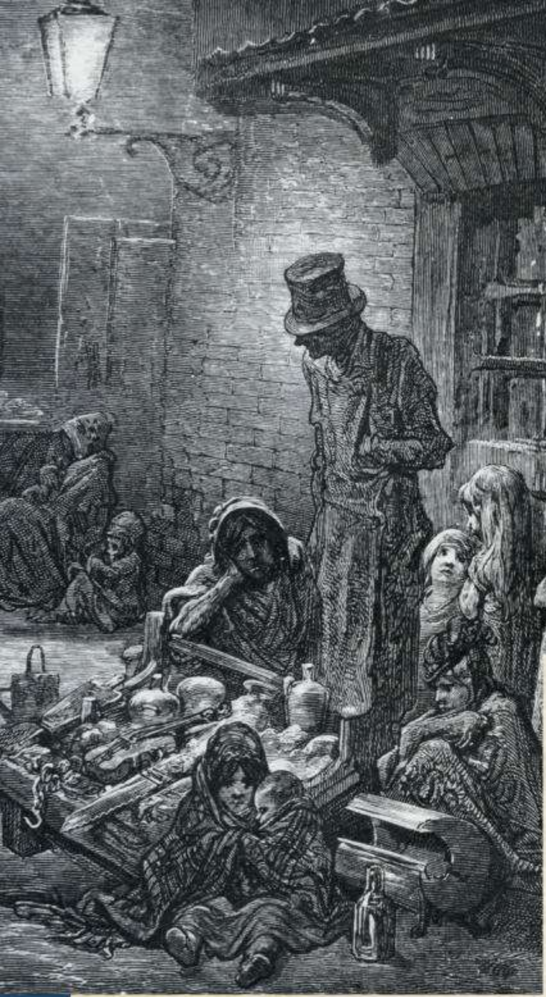
This bridge, as Dickens would have known it, was the John Rennie granite bridge (replaced in 1972 when the original was moved to Arizona, U.S.). Famously, Nancy meets Rose Maylie and Mr Brownlow here to try and save Oliver Twist.

TOWER OF LONDON

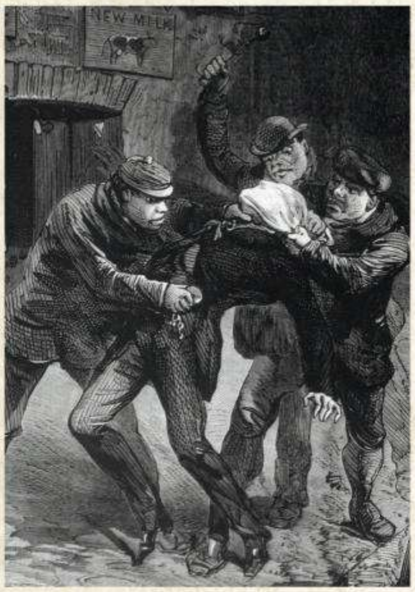
FEATURED IN: 9 BOOKS

The Tower is not only one of London's most famous and historic buildings, making it a common location in Dickens' books, but the author shares a modern connection too. Three ravens who have lived in the Tower have been named after Dickens' pet raven, Grip.

Alamy



Poverty was a huge problem in 19th-century London, with many families struggling to support their children



The capital was swamped by violent gangs, a subject Dickens wrote about in novels such as *Oliver Twist*

London, however, wasn't simply the ravenous centre of imperial greatness. It was a place of enormous activity, one that was energised by the development of the docks and the creation of railways, while innovation was seen in all areas of life, including the design of prisons. It was also a place of terrible poverty, something Dickens frequently reflected on.

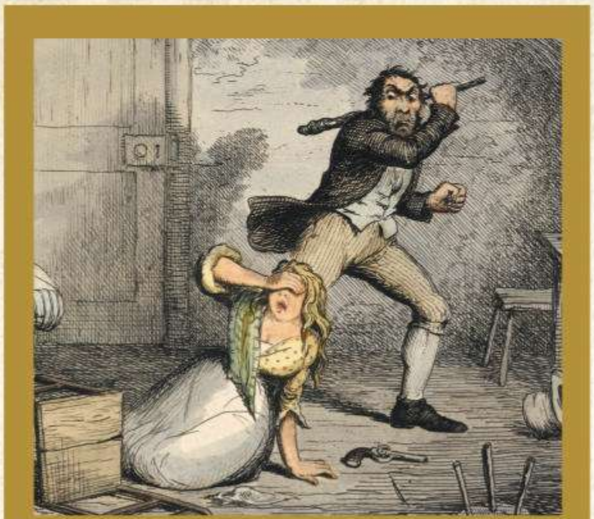
The Society for Bettering the Condition of the Poor noted in 1805: "Many of the inhabitants of the more crowded parts of the Metropolis suffer very severely under infectious fever… that in many parts the habitations of the poor are never free from the febrile infection; there being not only courts and alleys, but some public buildings, in which it has continued for upwards of 30 years past; and that, by means of the constant and unavoidable communication which exists between the different classes of the inhabitants of the Metropolis, and between the Metropolis and other parts of the kingdom, this dreadful disease has frequently been communicated from the London poor to country places, and to some of the more opulent families in the Metropolis."

A year later, in *A New and Appropriate System of Education for the Labouring Poor*, Patrick Colquhoun wrote of "the parents [of Westminster]… many of them are ignorant, and extremely ill educated, while not a few are… immoral and profligate… [for London and its environs:] at least 50,000 children are reared, and rearing up, every year, in the grossest ignorance and profligacy… the morals of the inferior classes of society, particularly in the metropolis, are rapidly declining."

BLOOD IN THE STREETS

The serial killings in Whitechapel in 1888 by 'Jack the Ripper' were the most dramatic example of the crimes that troubled London, a city plagued by misery and disorder - the flip side of its imperial greatness. This concern was frequently voiced in the press and overlapped with explicitly fictional accounts of the city, from Dickens to Doyle, most of which contributed to the same impression of London as a city of great deprivation as well as one of excess and luxury.

The impact of press reporting is seen in *Martin Chuzzlewit* when Tom Pinch arrives in London from Salisbury: "He was particularly anxious, among other notorious localities, to have those streets pointed out to him which were appropriated to the slaughter of countrymen; and was quite disappointed to find, after half-an-hour's walking, that he hadn't had his pocket picked. But on



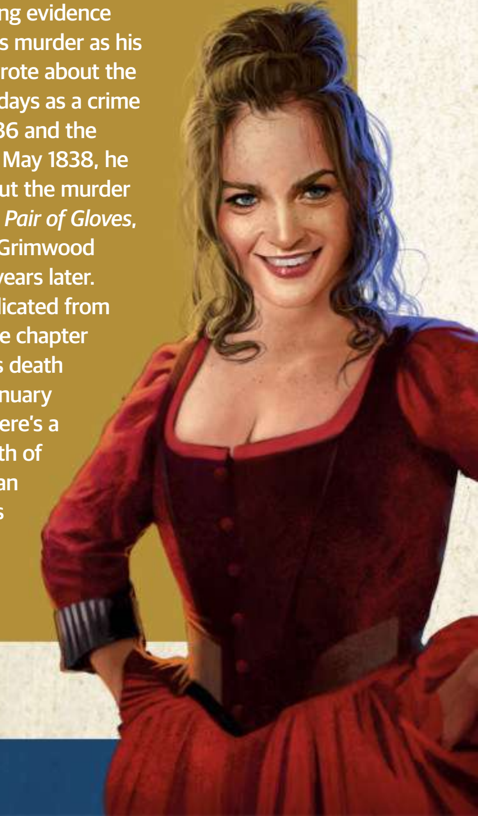
THE REAL-LIFE DEATH OF NANCY

Did a gruesome London murder inspire Dickens?

In what is possibly the most graphic and disturbing scene in any Charles Dickens book, the author described the brutal murder of Nancy by Bill Sikes in *Oliver Twist*. It's an event so dark than many adaptations of the book have tended to avoid portraying it in any detail. It's been questioned just why this scene is so violent in the context of the wider story, but author Rebecca Gowers highlighted a potential link when she wrote her novel *The Twisted Heart*, which was inspired by real events.

Gowers pointed to the real murder of a London sex worker named Eliza Grimwood in 1838. While some of the details differ, many of them are remarkably similar to Sikes' methods. Grimwood, who was in bed when she was attacked, was forced to her knees and stabbed repeatedly, with her killer continuing to slash at her after she'd died. In Dickens' book Nancy was clubbed.

The most compelling evidence that Dickens used this murder as his template is that he wrote about the real event. While his days as a crime reporter ended in 1836 and the murder took place in May 1838, he went on to write about the murder in his short story *The Pair of Gloves*, which discussed the Grimwood case by name many years later. *Oliver Twist* was syndicated from 1837 onwards, but the chapter that included Nancy's death was not seen until January 1839. It seems like there's a good chance the death of Eliza Grimwood was an inspiration to Dickens for his most harrowing scene.



"DOCKLAND WAS ALSO MORE MULTICULTURAL THAN ANY OTHER PART OF LONDON"

John Westlock's inventing a pickpocket for his gratification, and pointing out a highly respectable stranger as one of that fraternity, he was much delighted." In *Great Expectations*, Mr Wopsle, "imbrued in blood to the eyebrows," reads the newspaper aloud at the pub, delighting in the gory details of a recent murder.

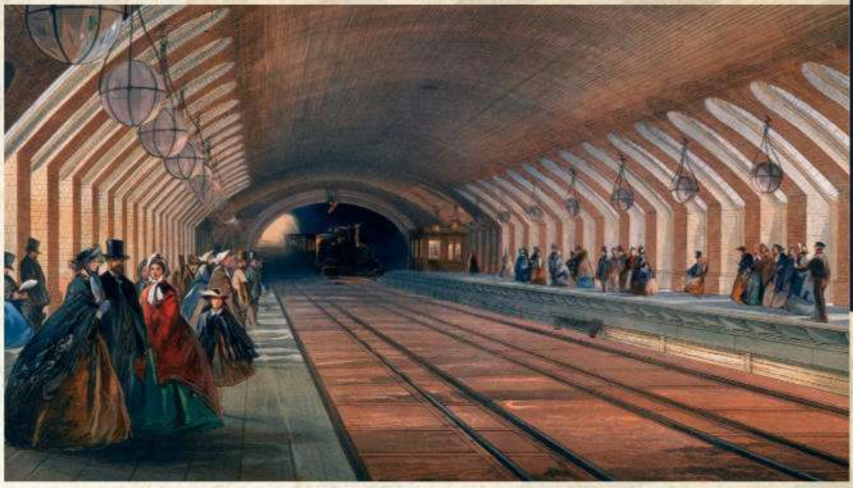
In effect, London became the subject of social exploration, such as by Henry Mayhew in his series of articles about the slums published in the *Morning Chronicle* in 1849 and then in his collection *London Labour and the London Poor*. There were also visual accounts, notably by Gustave Doré, whose illustrations brilliantly captured the cramped and cluttered streets of London.

The 'Jack the Ripper' killings were an apparent culmination of a menace already seen in other episodes, such as the garrotting scare of 1862. The resulting sense of menace was mocked in the satirical magazine *Punch*'s cartoon 'Going Out to Tea in the Suburbs. A Pretty State of Things for 1862', which showed three wealthy young ladies escorted by six armed men.

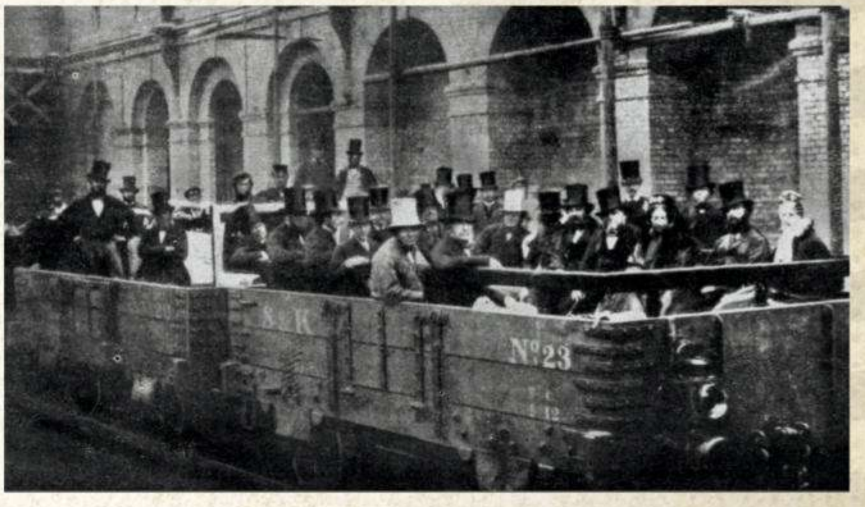
CRIMINAL CLASS

There are obvious problems with the sources, not least the extent to which they depicted middle-class perceptions of London life - something that Dickens could be accused of - and often in a moralised fashion. Moreover, the argument that there was a criminal class quite separate from the working poor has been queried by those who suggest that much crime was a matter of necessity by the latter. Indeed, the *Courier* newspaper noted on 12 October 1832: "Poverty, misery, and crime, are near-a-kin. When will the sense of mankind be turned to prevent rather than to punish the crimes to which the most culpable neglect drives unwilling but despairing offenders?"

Yet this approach could be taken too far, as there was not only criminality but organised criminal groups. Violence, theft, abuse and alcoholism were all major problems, while, alongside criminal networks, there was the often violent chaos of the street. This was a vision of London life that Dickens dipped into frequently, such as at the end of *Oliver*

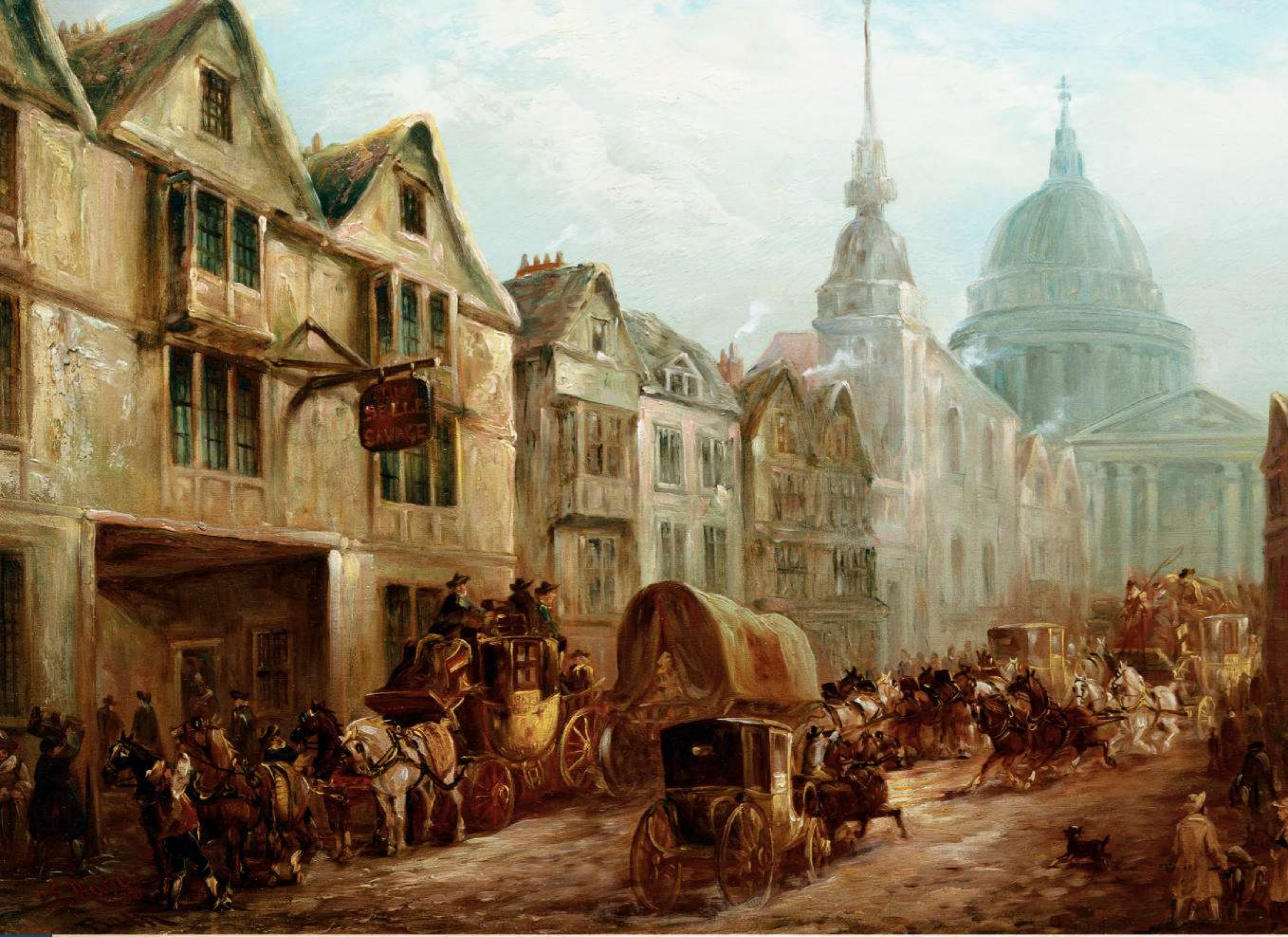


▸ The development of the London Underground transformed how people moved around the city



▸ William Gladstone opens the Metropolitan Railway in London in 1863, the beginning of the London Underground

▾ The very poorest in society often ended up in a workhouse, where they were given employment and a place to live

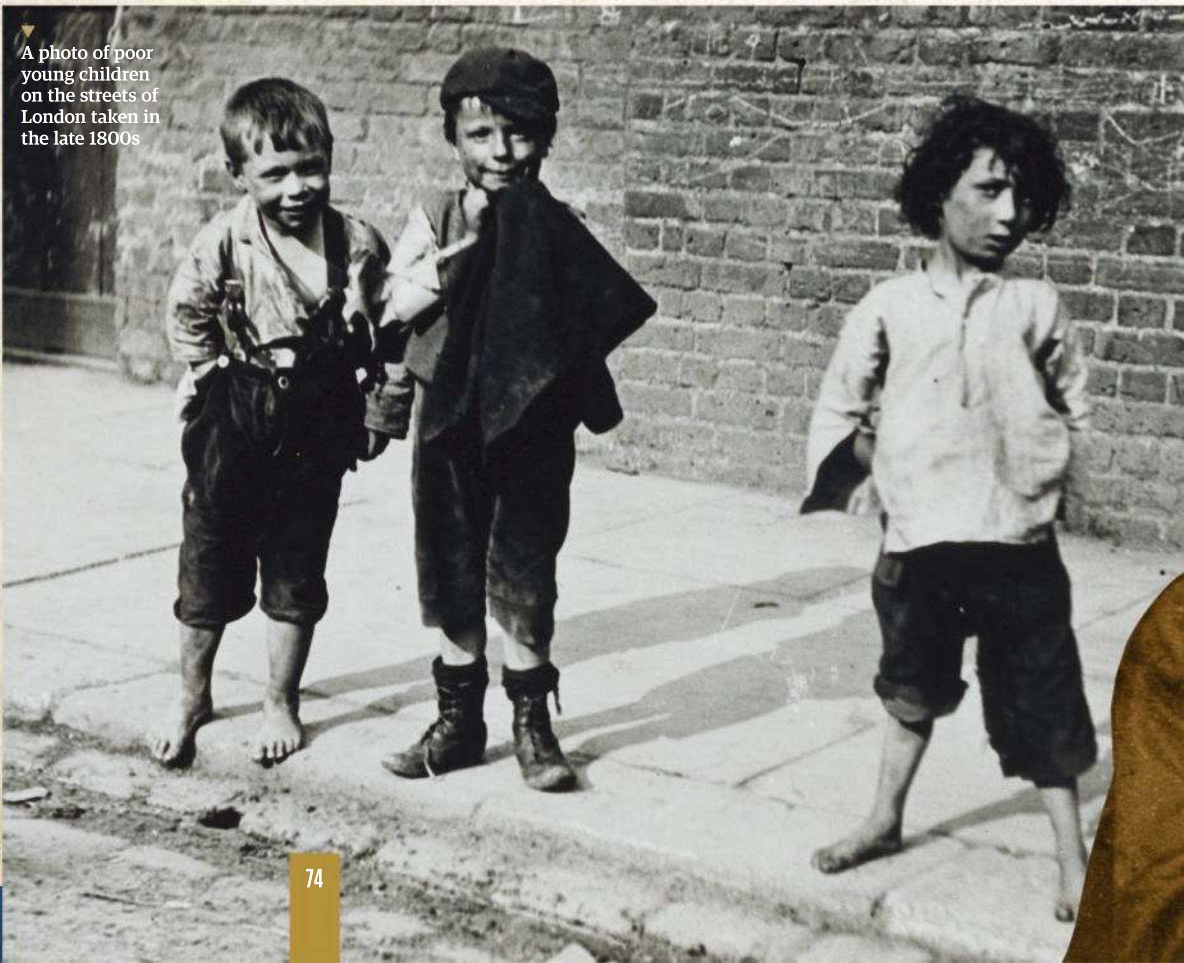


Twist, when the villainous Bill Sikes takes refuge in a rookery (a colloquial term for a slum).

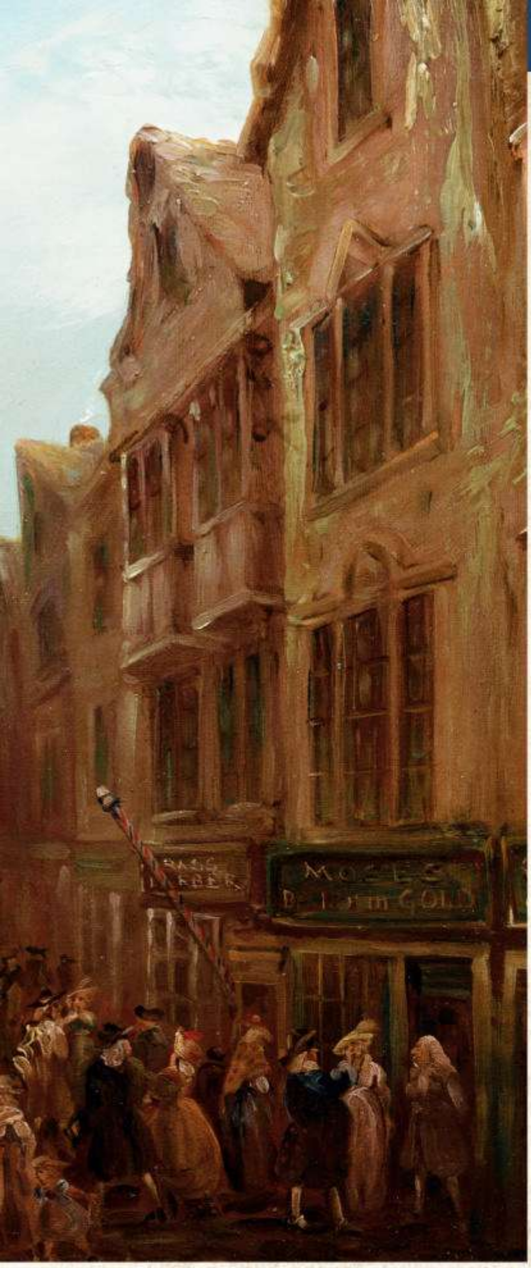
As the financial centre of the world, London offered Dickens the chance to write about fraud too, a crime of the rich and powerful. It was a prominent theme in a number of his works, notably with Merdle in *Little Dorrit* and Carker in *Dombey and Son*, but also with an insurance fraud of the 1830s, which is the point of reference in *Martin Chuzzlewit*. Godfrey Nickleby considers insuring his life before committing suicide, while in *Great Expectations*, Herbert Pocket wants to "buy up some good Life Assurance shares, and cut into the Direction".

LONDON SMOG

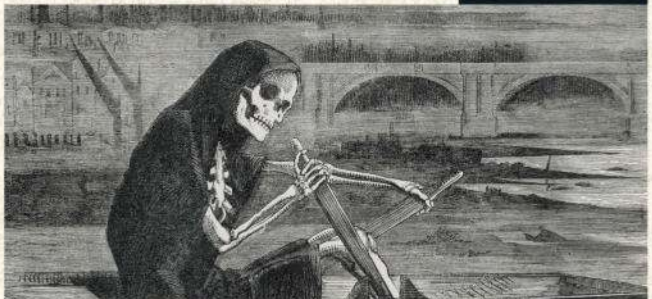
Crime, which in the case of the rich also included construction of cheap buildings with inferior materials for a quick profit, was not the sole blight on society: infectious disease was another. Sanitation fed back into the very dynamics of population growth, not least because of exposure to disease from



A photo of poor young children on the streets of London taken in the late 1800s



A classic scene of a busy London street with St. Paul's Cathedral dominating the skyline



The polluted River Thames depicted as the highway of death

Dickens' novels frequently blended his stories with a fierce social conscience

"RESPIRATORY DEATHS IN THE WINTER REFLECTED THE IMPACT OF AIR POLLUTION"

elsewhere in the world as London became a hub of international travel. Other major problems included the lack of clean water, as well as air pollution, notably in the form of smoke and fog, creating the smog with which London was often associated. The water question was in part one of sewage, with the filthy River Fleet known as the Black River of North London. The problem of polluted water was tackled head on as it was known to cause many diseases, but the smog was not really addressed until the mid-20th century.

In 1888, Henry James, the American novelist who settled in the city in 1869, praised the "magnificent mystifications" of London's fog: it "flatters and superfuses, makes everything brown, rich, dim, vague, magnifies distances and minimizes details, confirms the inference of vastness by suggesting that, as the great city makes everything, it makes its own optical laws."

The 1880s saw the most acute smogs, but the growth in population and fuel consumption had led to air pollution becoming steadily worse from early in the century; in 1853 the Smoke Nuisance Abatement Act was aimed at a phenomenon vividly described that year in Dickens' novel *Bleak House*. Inspection and enforcement made regulation difficult, but in any case legislation excluded the households where inefficient coal-fed open fires were a big cause of the smog. Londoners much preferred the term fog and saw it as part of the identity of the city. Brilliantly captured by painters such as the Frenchman Claude Monet, fog also provided opportunities for crime, caused accidents and helped prostitutes by providing cover from the police and making it easier for cautious clients to make an approach.

Respiratory deaths in the winter reflected the impact of air pollution from coal fires, and diarrheal infant mortality in the summer was an aspect of the continuing problems with clean water, while poverty and overcrowding both remained serious problems. Dickens powerfully captures the terrible situation in *Dombey and Son*, in which he urges: "follow the good clergyman or doctor, who, with his life imperilled at every breath he draws, goes down into their dens, lying within the echoes of our carriage wheels and daily tread upon the pavement-stones. Look round upon the world of odious sights – millions of immortal creatures have no other world on earth… Breathe the polluted air, foul with every impurity that is poisonous to health and life; and have every sense, conferred upon our race for its delight and happiness, offended, sickened and disgusted, and made a channel by which misery and death alone can enter."

The heatwave of 1858 turned the already noxious Thames, filled with sewage and animal carcasses, into an even more over-ripe state that came to be called the Great Stink. This led to the temporary abandonment of Parliament and to a major programme of sewerage works.

In 2021, marine archaeologists found a compacted layer of Victorian waste in the Thames near Tate Modern that came from this era. The anaerobic environment of sewage baked at the riverside in hot dry weather had preserved the smell. A member of the Institute for Digital Archaeology referred to "a very distinctive odour of putrefaction, human waste and sulphur… it's like a body blow when you smell it. It just stops you in your tracks."

A CITY OF CHANGE

Downstream, the Victoria Embankment was built in 1862–70 as part of the transformation associated with celebrated civil engineer Joseph Bazalgette, one that removed the broad tidal range as well as creating new road links along the river shores. On the opposite bank, the Battersea Marshes had been drained with the encouragement of Prince Albert, and in accordance with legislation of 1846. Battersea Park opened in 1858, the same year as Chelsea Bridge, greatly improving a once marginal area.

Poor relief served to link concerns about wages and cost, and notably so in periods of economic crisis. By the end of the century London provided places for nearly a quarter of those on indoor relief (workhouses) in England and Wales.

London in the time of Dickens was a city that never stood still and, as he often portrayed in his books, if you didn't have enough wealth to duck out of the way you were likely to be trampled by the unstoppable march of progress.

The man who best captured the city's remarkable transformation was laid to rest in Poets' Corner in Westminster Abbey in 1870, which was in fact in contrast to Dickens' desire to be buried at Rochester Cathedral in Kent in an "inexpensive, unostentatious, and strictly private manner". Having seen the true nature of London, perhaps it's no surprise that he longed to spend eternity far from its cramped and uncaring streets.

© Getty Images, Alamy

Day in the life of

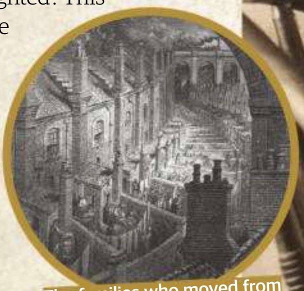
A CHILD LABOURER

Risking life and limb to bring home a pittance, Britain, 19th century

A British census conducted in 1841 reported that almost 107,000 children were employed in the textile industry alone. The reason for this sudden boom in child labour was no mystery; as industry moved from the fields to the factories, families poured into the cities to find employment. For the factory owners, children were the obvious choice for their new workforce; not only were they small enough to move under the machines, but they could also get away with paying them less than adults, though their workload was equal. Although laws were eventually passed, child labour continued in Europe well into the 20th century.

GO TO WORK

All children would need to be at the mill at 6 a.m., and 5 a.m. during busy periods. One form of punishment for tardiness was to be 'weighted'. This involved a heavy weight being tied to the offender's neck before they were forced to walk up and down the factory. There were even cases of children being dragged to the factory naked, holding their clothes, to ensure they would not be late even by a minute.



The families who moved from the country to the cities were forced to live in cramped and polluted conditions

WORK TIRELESSLY

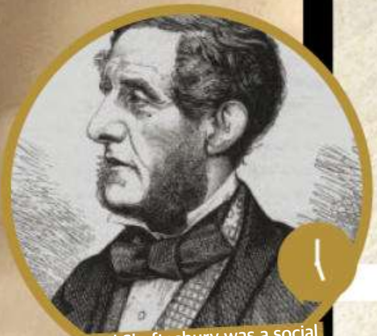
Tasks appointed to children varied depending on their size, gender and age. The youngest and smallest children would work as scavengers, squeezing under the machinery while it was still in motion to pick up scraps of cotton that had fallen to the floor. 'Piercers' were small girls who mended broken threads. The most common employment of children was to keep the machines oiled, working and supplied with thread.

EAT LUNCH

Child labourers would only get 30 minutes to eat lunch. Because they would need a lot of energy, their diet was high in carbohydrates. Common foods were oatcakes, porridge, gruel and beer. Meanwhile, water would be difficult to get because much of it was polluted, and milk and dairy products were often too expensive.

Eleven-year-old Nannie Coleson made $3 a week as a looper in the Crescent Hosiery Mill, Tennessee, at the start of the 20th century

> **“ANYONE WHO WAS FOUND DISOBEYING THESE RULES OR SLACKING WOULD BE BRUTALLY PUNISHED”**



Lord Shaftesbury was a social reformer who campaigned for children's rights during the Industrial Revolution

SUFFER AN INJURY

The Industrial Revolution filled the factories with large, heavy and dangerous new equipment. Although these machines increased efficiency, they posed great danger to the children who worked with them. Not only did the heavy amount of dust encourage respiratory diseases, but children would also suffer stunted growth and severe back pain. Those working in mills could bruise, skin or even lose their fingers on the dangerous machinery. It wasn't until the Factory Act of 1833 that conditions began to improve.

COLLECT WAGES

The most attractive thing about child workers is that they were far cheaper than their adult alternatives. As there was no legislation in place, child wages varied widely during the Industrial Revolution. On average, child workers were paid about ten to 20 per cent of the equivalent adult's wages – while men could earn 15 shillings (75 pence) a week, children earned just three shillings (15 pence).

ATTEMPT ESCAPE

Many of the children who worked in these dangerous factories were orphan apprentices who received no wages but instead were paid in inadequate food, shelter and clothing. Because sometimes these orphans would attempt to escape, they were locked up when not working. Any children who did run away could be sent to prison, and rebellious would-be runaways had shackles riveted to their ankles to prevent any chance of escape.

RECEIVE PUNISHMENT

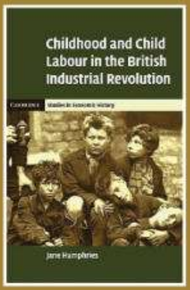
Factories operated with a very strict set of rules, and anyone who was found disobeying these rules or slacking would be brutally punished. Verbal abuse and beatings by supervisors were very common, and there were reports of children being beaten so brutally that they later died as a result of their injuries. A brutal punishment for girls proud of their hair was haircutting, and children found slacking were held by their legs and dipped into cisterns filled with water.

WORK INTO THE NIGHT

Child labourers would often work until nine or ten at night; on Saturdays they could even work until midnight. When the 1833 Factory Act was passed, set working hours finally came into effect, with children aged nine to 13 only allowed to work eight hours, 14- to 18-year-olds no more than 12 hours, and those under nine were prohibited from working at all. This also brought compulsory education of two hours a day into effect.

HOW DO WE KNOW THIS?

Child Workers and Industrial Health in Britain by Peter Kirby deals specifically with the occupational health of children employed in the factories during the period, while *Childhood and Child Labour in the British Industrial Revolution* by Jane Humphries provides an account of working-class childhood. The investigations carried out prior to the passing of the Factory Acts provide clear information about the appalling conditions children were working in. There is also a wealth of interviews with child labourers of the time, most notably those interviewed for the *Lion* newspaper.



Childhood and Child Labour in the British Industrial Revolution

Jane Humphries

© Alamy

VICTORIAN CRIME

While overseas the British Empire was flourishing, in London, the city of fog, a grisly war was waging between the emerging criminal class and a fledging police force

Written by Frances White

As Queen Victoria ascended to power, England's influence over the world spread like a blot of spilt ink, and this dark mark seeped into the houses and alleyways of the country's overpopulated cities. Executions of dastardly criminals drew increasing crowds, and headlines warned of the crime wave washing over the country. Thieves lingered in shaded alleys, there were violent acts of garrotting against the rich and influential, and a well-dressed man who killed for fun was known only by his eerie nickname, Jack the Ripper.

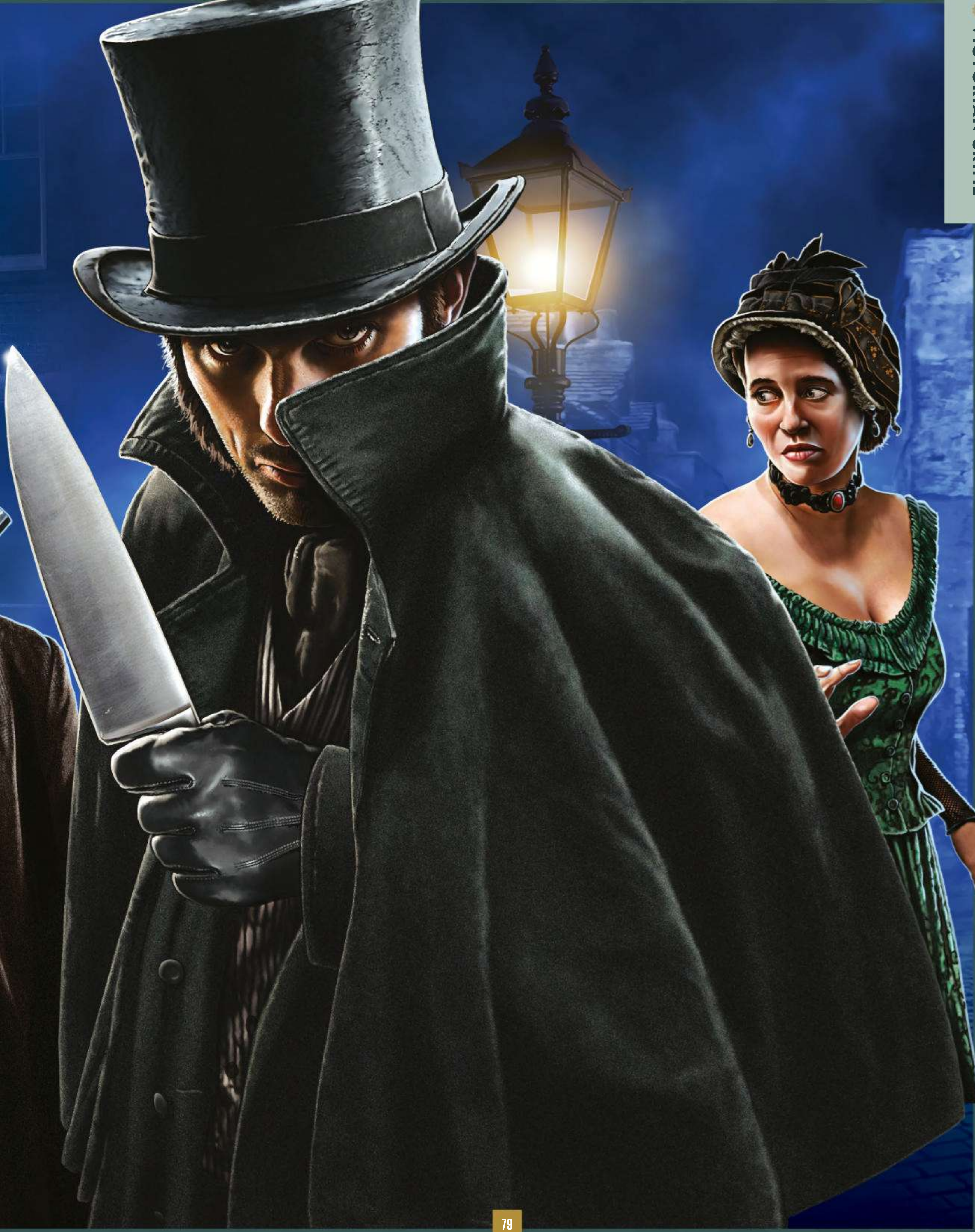
The Industrial Revolution, with its smoke-spewing factories, created a buzz of excitement in the cities, but life was not so full of opportunities for the lower-class workers. As more families flooded into the cities, poverty thrived. It was soon followed by its frequent bedfellow, crime.

Rookeries sprung up around London – nests of winding alleys, dead ends and shadowed corners where thieves, prostitutes and cheats could scheme and fester. They were a den of gloomy places for criminals to hide and a twisted maze in which to lose the police. One of the central breeding grounds for this new and dangerous class was the neighbourhood of Whitechapel, along with the surrounding areas of Bethnal Green, Wapping and Mile End, not to forget the ever-growing slums of Spitalfields. These run-down and over-populated places became cut off from the rest of the city, and crime flourished.

Children born in these dens of decay had little hope of leading an honest life. Their choice was a stark one: face the cruel and dangerous conditions of the workhouse, or try to make it on the streets. Better to take a chance on the short and fast life of a criminal than the inevitable poverty that hung all around them like the thick black smoke that covered the city. Until 1870 there was no compulsory education, so orphaned, abandoned or poverty-stricken youngsters gained a very different set of skills on the streets.

As they grew up, the street urchins outgrew the silken handkerchiefs and measly rewards dispensed at the mercy of their masters. The common path for the older pickpocket was to join the swell mob. These older, experienced crooks were debonair criminals who earned the trust of their unwitting victims before bleeding them dry.

On paper, it seemed Victorian London was the safest period in the city's history, but in reality a lack of faith in the police left many crimes unreported, and all citizens knew to keep their wits about them or else leave certain areas significantly lighter than they entered them.



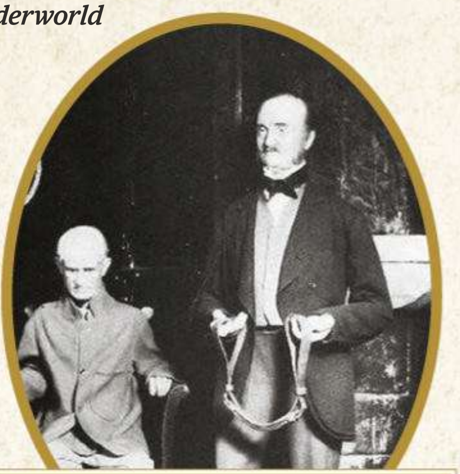
VICTORIA'S MOST WANTED

The most deadly and dastardly criminals of the Victorian underworld

AMELIA DYER

1837–96

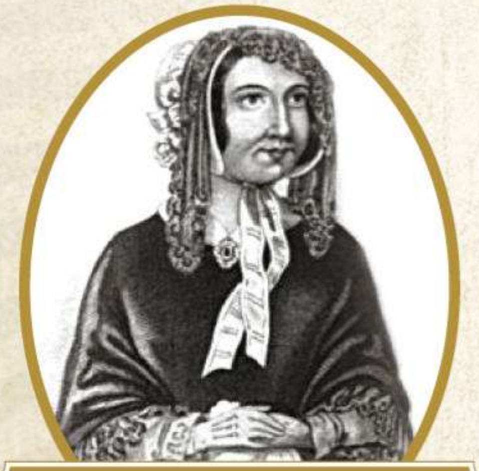
NICKNAMES Ogress of Reading, The Reading Baby Farmer
CRIME After training as a nurse for many years, Dyer opened her home to young pregnant women who had conceived out of wedlock. When the babies were born she promised the mothers she would provide a safe and loving home for a one-off payment. However, instead of providing homes, Dyer killed the children and pocketed the profits. Although she aroused suspicion, she was able to avoid detection thanks to various conveniently timed stays in mental hospitals. When her crimes were finally discovered, Dyer had been responsible for 200–400+ child deaths.
PUNISHMENT Hung from the neck until dead
LAST WORDS "I have nothing to say."



CHARLES PEACE

1832–79

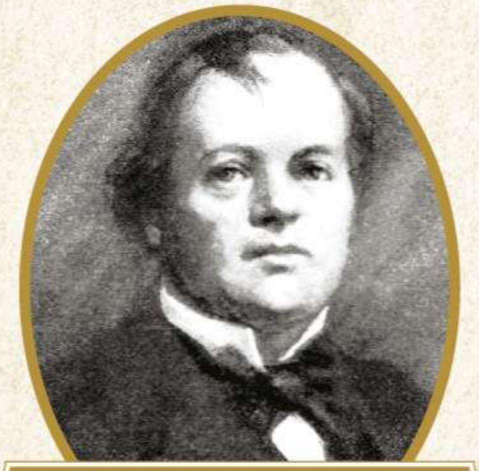
NICKNAME The Banner Cross Killer
CRIME Beginning with small robberies, Peace was in and out of jail throughout his life. In 1876, he killed a police officer while robbing a house, but instead William Habron was found guilty. Peace later became obsessed with a woman called Katherine Dyson. One night her husband caught him stalking her and Peace shot him dead. Peace was eventually arrested despite attempting to escape by throwing himself from a train window.
PUNISHMENT Hung from the neck until dead
LAST WORDS "Sir, if I believed what you and the church say that you believe, even if England were covered with broken glass from coast to coast, I would walk over it [...] and think it worth while living, just to save one soul from an eternal hell like that!"



MARIA MANNING

1821–49

NICKNAME Bermondsey Horror
CRIME Maria Manning was a Swiss domestic servant fascinated with the trappings of wealth so decided she would marry a rich man to become a lady. She set her sights on Patrick O'Connor. However, she ended up marrying Frederick Manning, a poor railway guard who promised he was set to inherit a fortune. This was a lie, so Maria continued her affair with O'Connor, which Manning encouraged. The couple invited him over for dinner one evening after digging a grave under the kitchen floor. When he arrived she shot him, but the wound was not fatal, so Manning battered him to death with a chisel.
PUNISHMENT Hung from the neck until dead
LAST WORDS None reported



WILLIAM PALMER

1824–56

NICKNAMES The Rugeley Poisoner, The Prince of Poisoners
CRIME Palmer was involved in crime from an early age, facing allegations of stealing. He later became a doctor, but death seemed to follow him. Within weeks of his marriage to Anne Thornton her wealthy mother was dead, and four of his children died mysteriously. In debt, Palmer took out life insurance on his wife and brother and they both died soon after. The murder of John Cook finally exposed him. Cook was poisoned by Palmer, who then interfered with the post mortem. Despite this, poisoning by strychnine was ruled as the cause of death and Palmer was found guilty. It's believed he killed 14 people.
PUNISHMENT Hung from the neck until dead
LAST WORDS "Cook did not die from strychnine."

CRIMINAL SLANG

A guide to the popular slang terms of Victorian London

AREA-SNEAK: Opportunistic burglar

BEARER UP: Someone who uses a female accomplice to distract men while they rob them

BLUE BOTTLE: Policeman

BONNETING: Tipping a man's hat over his head to make him easier to mug

BROADSMAN: A cardsharp

BUG-HUNTERS: People who rob drunks, usually at night

BUTTONER: A sharper's assistant, usually entices the targets

CRACKSMAN: A burglar or safecracker, a thief who breaks locks

DRAGSMAN: A thief who targets occupants of carriages

FLASH HOUSE: A public house that serves as the hangout of criminals

GONOPHS: Child thieves

HOISTERS: Shoplifters

KIDSMAN: Someone in charge of a troupe of child thieves

MAGSMAN: Confidence tricksters, usually inferior

MALTOOLER: A pickpocket who steals from those riding the omnibus

PRIG: A thief

RAMPSMEN: A hoodlum

ROOKERY: A slum

SHARPER: A swindler, usually involved in rigged card games

SMASHERS/SHOFULMEN: Counterfeiters

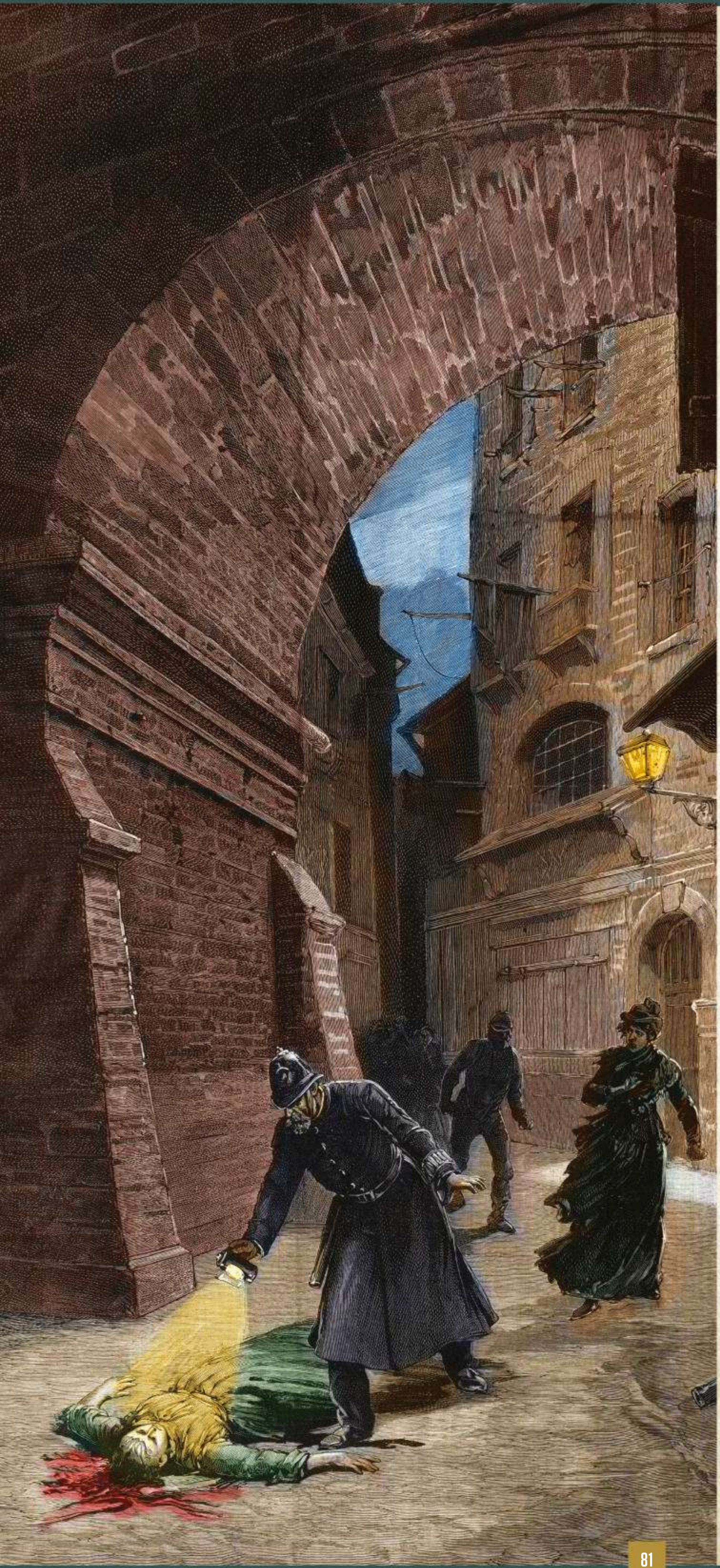
SMATTER HAULING: Stealing handkerchiefs from men

SPEELERS: Gamblers

SWELL MOB: Elite pickpockets, usually well-dressed and appearing respectable

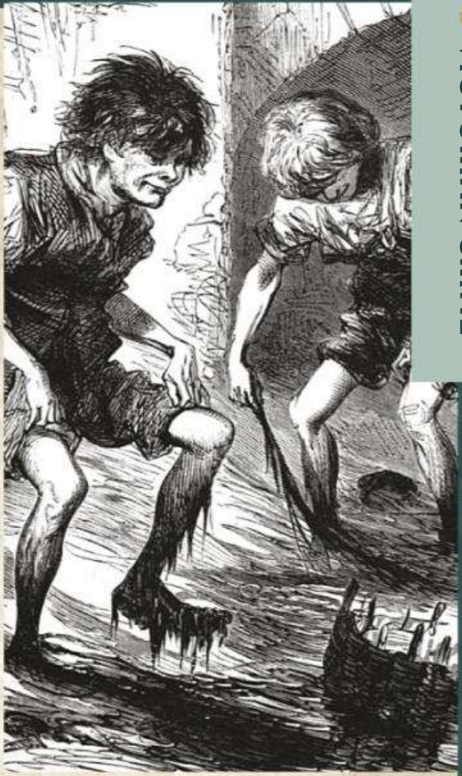
THE FAMILY: The criminal underworld

THIMBLE-RIGGER: A con man who dupes people with the shell game, where an item is hidden under one of three cups



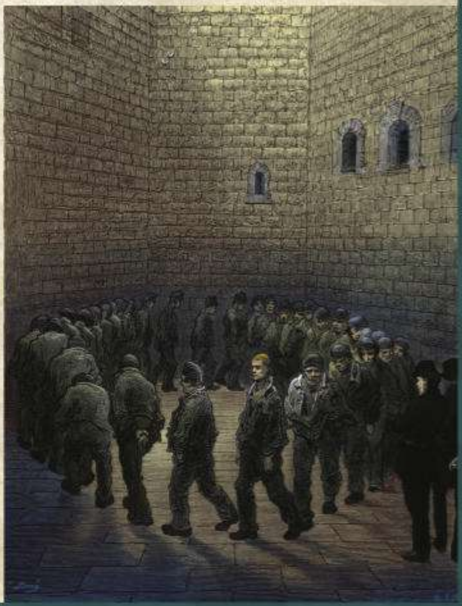
The Metropolitan Police Force was established after a sharp rise in crime in Victorian London

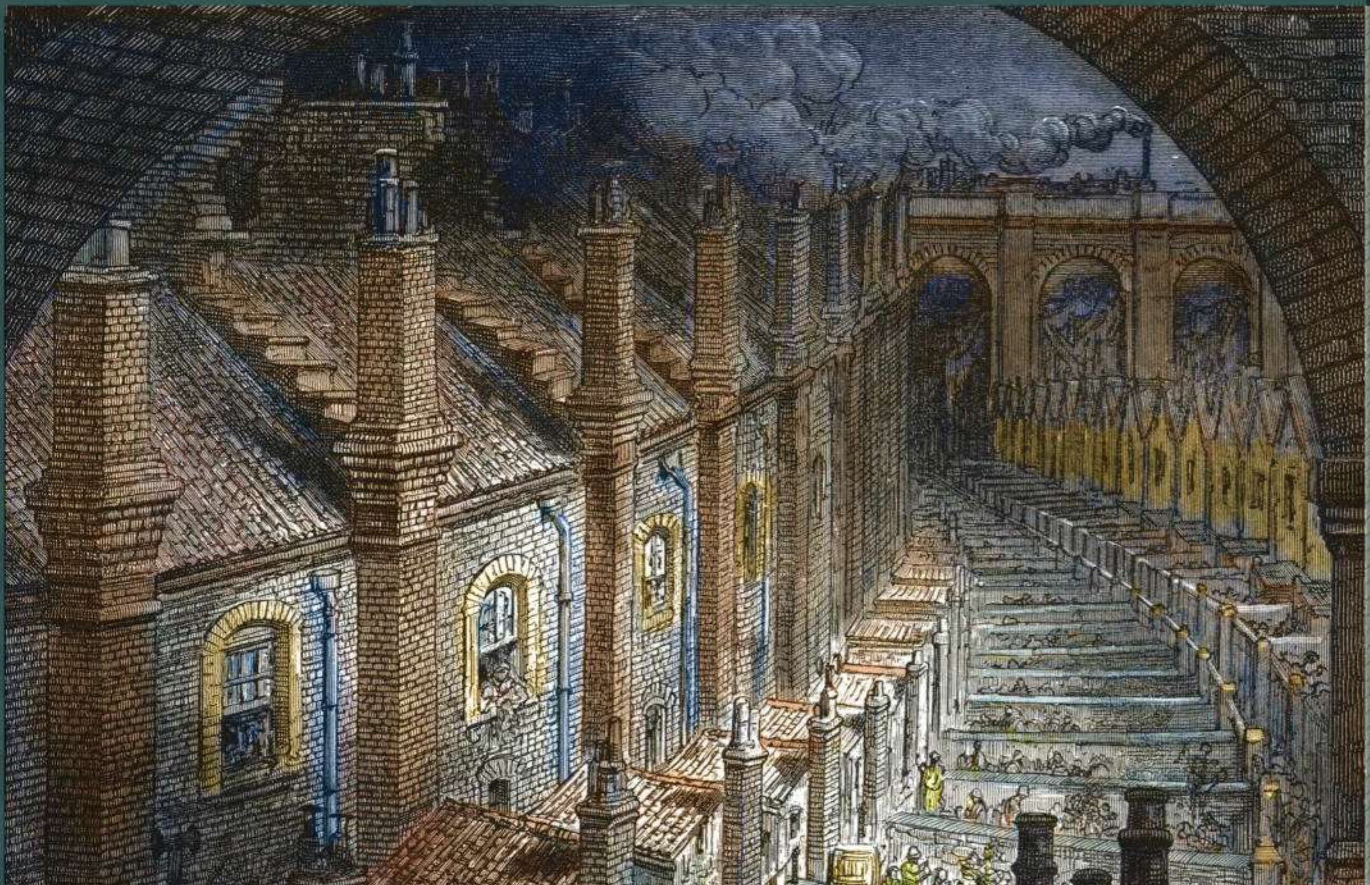
Mudlarks scavenged in river mud for lost treasures



The nickname 'Bobbies' was the result of Robert Peel's decision to make the force directly responsible to himself in the Home Office

Prisoners were known to take their own life to escape the mindless monotony of the gaol





Many houses in Victorian London contained multiple families

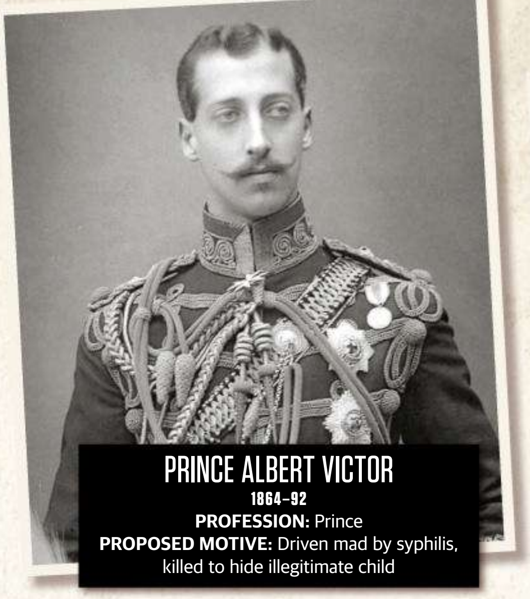
WHO WAS JACK THE RIPPER?

Unsolved murders in 19th-century London were not uncommon. The vast majority of victims were prostitutes, and the bodies of these fallen women were found so often that it's impossible to estimate just how many were murdered. But there was one set of prostitute murders so sinister and horrifying that the mystery surrounding the killer's identity fascinates people to this day.

When the corpse of Mary Ann Nichols was discovered on 31 August 1888, it was butchered so horrifically that it was deemed the work "of a madman". It was treated as yet another prostitute murder until a week later a similarly butchered corpse was found. The police soon realised they weren't dealing with a random act of violence but a serial killer. As the horrors of the murders filled the headlines, the police received a mysterious letter signed by "Jack the Ripper", and the dark legend was born.

As the murders continued, suspect after suspect was arrested and then released. The Whitechapel murders dominated the newspapers and the police seemed constantly one step behind "saucy Jacky". First butchers were accused, then Jews were in the spotlight, and then anyone with even the faintest link to a victim became a suspect.

Then, suddenly and without warning, Jack vanished into the shadows. Ever since, people have continued to attempt to determine his true identity, but the answer to this bloody mystery seems to have been lost in the dark and winding Victorian slums where he claimed his unfortunate victims.



PRINCE ALBERT VICTOR

1864–92

PROFESSION: Prince

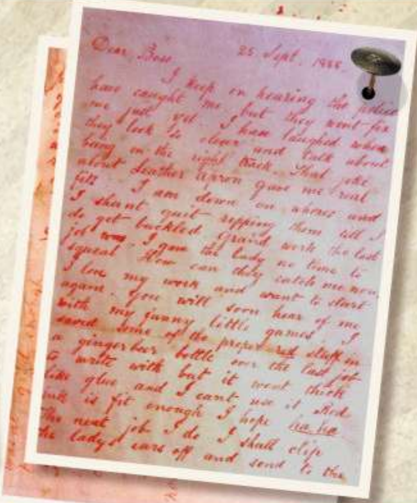
PROPOSED MOTIVE: Driven mad by syphilis, killed to hide illegitimate child

ELIZABETH STRIDE

BODY DISCOVERED: 1 a.m., 30 September 1888

LOCATION: Dutfield's Yard, Berner Street

WOUNDS: Cut throat



Dear Boss 25 Sept. 1888.
I keep on hearing the police
have caught me but they wont fix
me just yet. I have laughed when
they look so clever and talk about
being on the right track. That joke
about Leather Apron gave me real
fits. I am down on whores and
I shant quit ripping them till I
do get buckled. Grand work the last
job was. I gave the lady no time to
squeal. How can they catch me now.
I love my work and want to start
again. You will soon hear of me
with my funny little games. I
saved some of the proper red stuff in
a ginger beer bottle over the last job
to write with but it went thick
like glue and I cant use it. Red
ink is fit enough I hope ha. ha.
The next job I do I shall clip
the lady's ears off and send to the

ANNIE CHAPMAN

BODY DISCOVERED: 6 a.m., 8 September 1888

LOCATION: 29 Hanbury Street

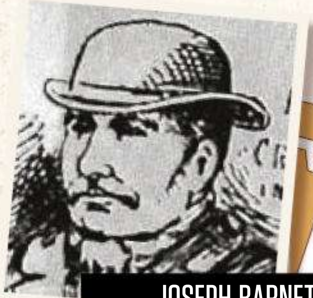
WOUNDS: Cut throat, abdomen ripped open, uterus removed

MARY JANE KELLY

BODY DISCOVERED: 10.45 a.m., 9 November 1888

LOCATION: 13 Miller's Court, Spitalfields

WOUNDS: Cut throat, abdomen emptied of most organs, heart missing, face mutilated

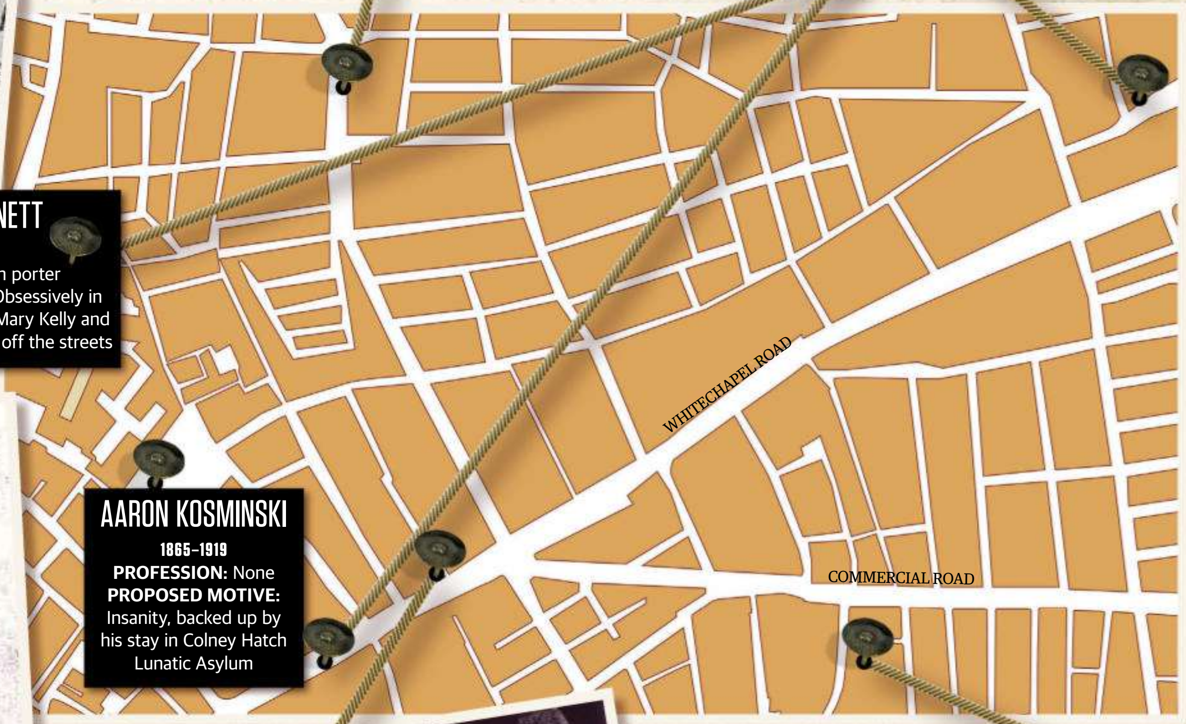


JOSEPH BARNETT

1858–1927

PROFESSION: Fish porter

PROPOSED MOTIVE: Obsessively in love with the prostitute Mary Kelly and killed others to scare her off the streets



AARON KOSMINSKI

1865–1919

PROFESSION: None

PROPOSED MOTIVE: Insanity, backed up by his stay in Colney Hatch Lunatic Asylum

DR THOMAS NEILL CREAM

1850–92

PROFESSION: Abortion doctor

PROPOSED MOTIVE: General sadistic tendencies, his supposed last words were "I am Jack the…"

MARY ANN NICHOLS

BODY DISCOVERED: 3.40 a.m., 31 August 1888

LOCATION: Buck's Row, Whitechapel

WOUNDS: Cut throat, abdomen ripped open, many other incisions

CATHERINE EDDOWES

BODY DISCOVERED: 1.45 a.m., 30 September 1888

LOCATION: Mitre Square

WOUNDS: Cut throat, abdomen ripped open, left kidney and most of uterus removed, face mutilated

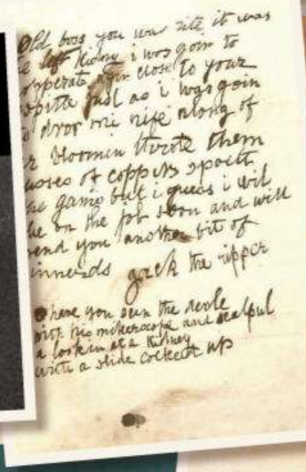
Miller's Court, where Mary Jane Kelly's body was found butchered

JAMES KELLY

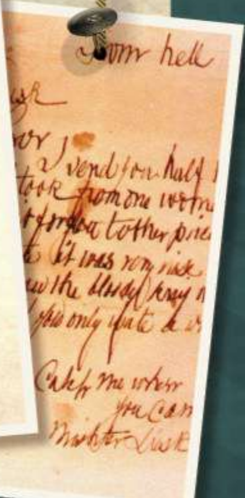
1860–1929

PROFESSION: Furniture upholsterer

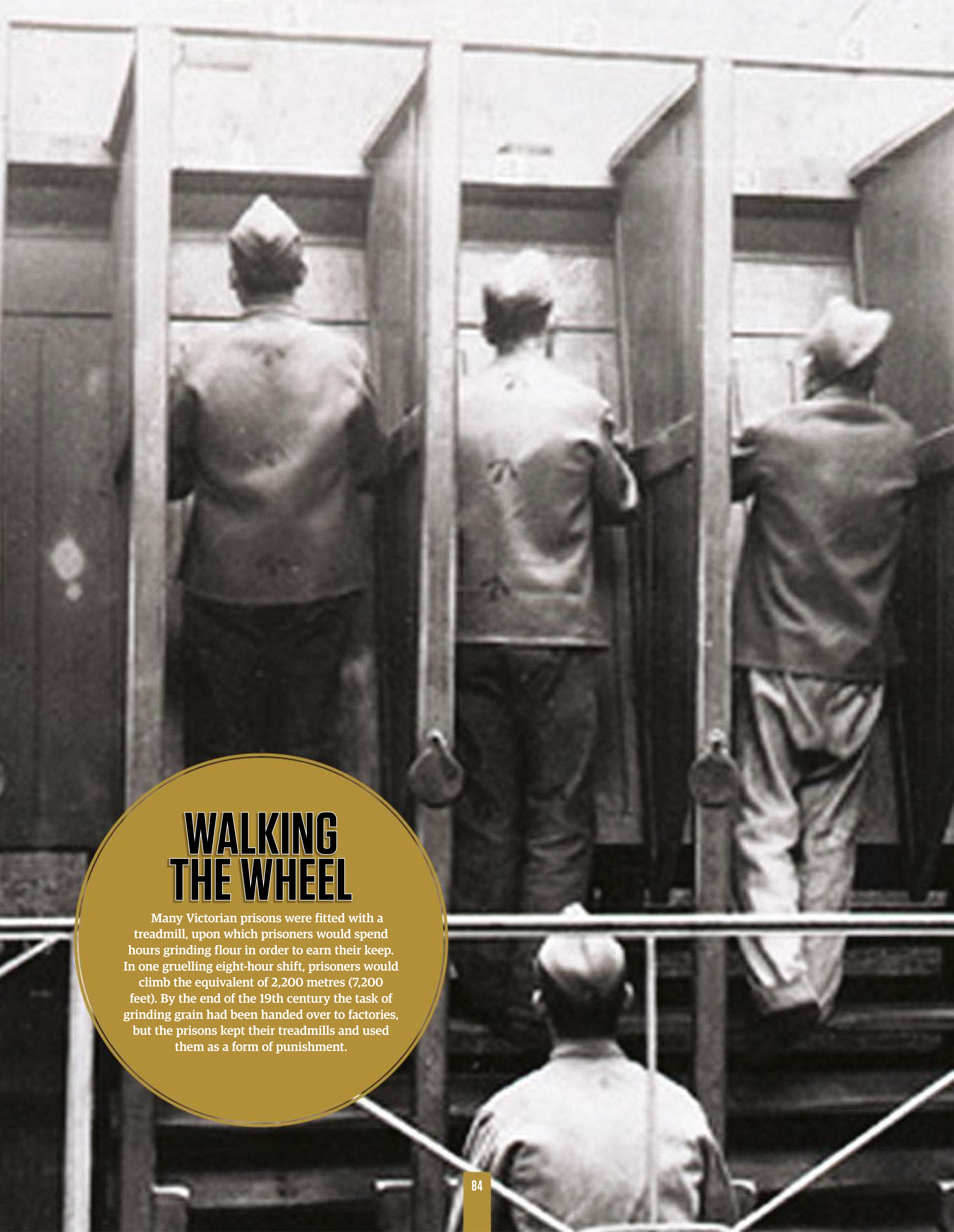
PROPOSED MOTIVE: Already murdered his wife; showed a strong dislike for prostitutes; insanity



Old boss you was rite it was
e left kidny i was goin to
operate agin close to your
spitle just as i was goin
dror mi nife along of
r bloomin throte them
uses of coppers spoilt
he game but i guess i wil
be on the job soon and will
end you another bit of
innerds jack the ripper
O have you seen the devle
with his mikerscope and scalpul
a lookin at a kidney
with a slide cocked up



From hell
usk
or
I send you half
took from one wom
tother pie
it was very nise
w the bloody kny
you only wate a
Catch me when
you Can
Mishter Lusk



WALKING THE WHEEL

Many Victorian prisons were fitted with a treadmill, upon which prisoners would spend hours grinding flour in order to earn their keep. In one gruelling eight-hour shift, prisoners would climb the equivalent of 2,200 metres (7,200 feet). By the end of the 19th century the task of grinding grain had been handed over to factories, but the prisons kept their treadmills and used them as a form of punishment.

On 20 July 1829, Peel approved the establishment of a force of 895 constables, 88 sergeants, 20 inspectors and eight superintendents

BIRTH OF THE METROPOLITAN POLICE

As crime became organised and social disorder grew, it put an immense strain on the dated Tudor system of policing. Prior to the Metropolitan Police Act introduced by Home Secretary Robert Peel in 1829, small parishes and market towns only had a constable and the local watch and ward to maintain order. Meanwhile, in London, the Bow Street Runners, part publicly funded detectives, became the first incarnation of what is known today as a professional police force. When Peel's Metropolitan Police Force took to the streets of London in 1829, it was to a city very much in need of law and order.

A thousand new policemen were hired to supplement the existing 400. They were given weekly pay and distinctive bottle-blue uniforms; policing became a full-time profession with one central goal – the detection and prevention of crime. The force was specially designed to represent a neutral good – they were distanced from the military and were armed only with a truncheon and rattle (though some did later carry flintlock pistols). Despite Peel's best efforts, the police were initially not well liked. Many citizens saw them as a threat to civil liberties and they earned unfavourable nicknames such as 'blue devils' and 'Peel's bloody gang'. Despite their focus being to prevent disorder, many policemen were attacked, impaled, blinded and even killed. Even with the thorough selection process wannabe officers underwent, many of them were arrested for being drunk on duty, while others were found guilty of corruption. The very first policeman, who had been given the number one, was sacked after just four hours on the job for drunkenness.

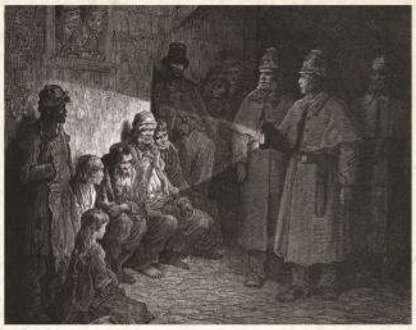
Despite the negative public reaction, the preventative measures used by the police were successful and crime did appear to decline. It is certain that the presence of police dissuaded criminals, but often this merely pushed them into the areas of London where the police did not operate. Wandsworth attracted so many criminals eager to escape the law that it became known as 'Black Wandsworth'. Many boroughs in England and Wales as a whole were hesitant to set up their own forces, and by 1848, 22 boroughs still had no official police force. However, although implementation was slow, eventually police forces spread across the country, and in 1856, 73,240 people were arrested in London alone.

For those found guilty, a combination of backbreaking work and mind-numbing monotony awaited in the gaols. The Victorian era was a time of dramatic change in the prison system and new techniques were being employed across the country. Hulks – old sailing ships originally used to hold prisoners to be transported – were increasingly used to house ordinary prisoners. Conditions on the hulks, which were stripped of their sails, were horrific and cholera was rife as filthy, polluted water from the Thames was used for both washing and drinking.

Techniques of isolation and segregation were employed to encourage reflection. At Pentonville Prison (dubbed a 'convict academy'), prisoners were stripped of their names and referred to by their cell number, which was embossed on a brass badge pinned to their chest. They wore a brown cloth cap with a mask that covered their faces – their voices and stories hidden from the world.

Hard labour was first employed as a way to encourage productivity from prisoners, with the treadmill, a large cylinder with steps that the

It was not uncommon for officers' rattles to be used against them



It took some time for the new police force to gain respect from the public

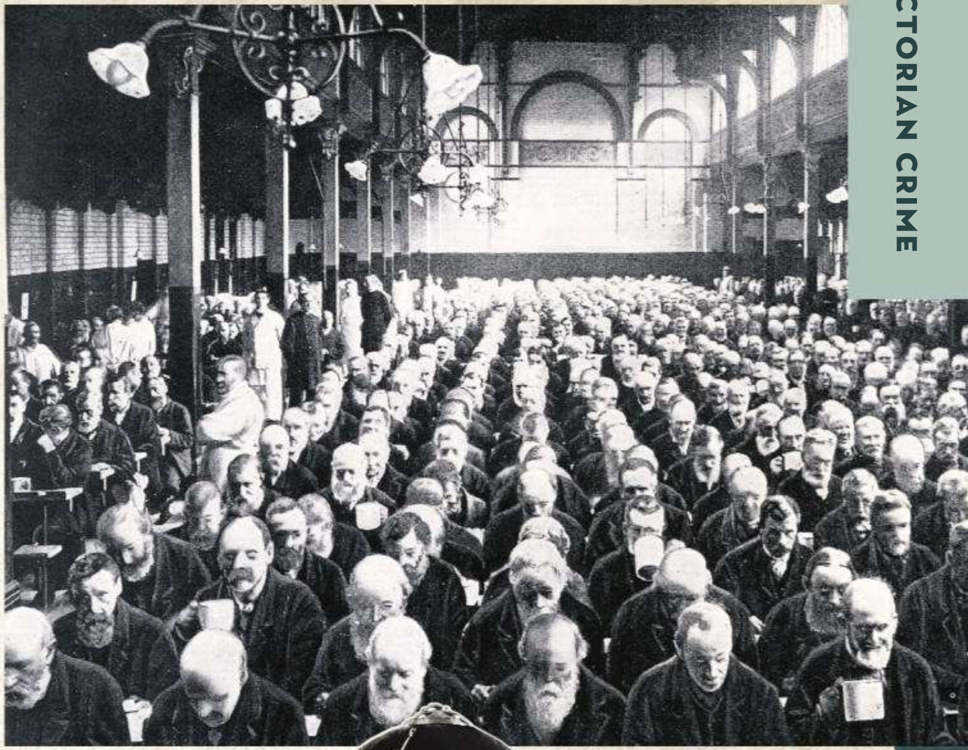
CRIME & PUNISHMENT

Arson	15 years' transportation
Abandoning family	21 days' hard labour
Stealing onions	Seven years' penal servitude
Begging	21 days' hard labour
Murder	Hanged from the neck until dead
Assault	21 days' imprisonment
Trespassing	One month's hard labour/ fined 27 shillings
Stealing a waistcoat	Six months' hard labour

prisoners monotonously climbed for up to eight hours a day, producing flour for the prison to sell. However, in the later part of the 19th century, there was no end product for this back-breaking task and it – along with a host of other mindless exercises – was designed only to break the prisoners' spirits. The gaols wished to establish themselves as a spectre of pain and suffering to deter criminals. Because the poor outside were suffering under terrible conditions, the government was keen to ensure prisons represented a bleaker outlook than the workhouse.

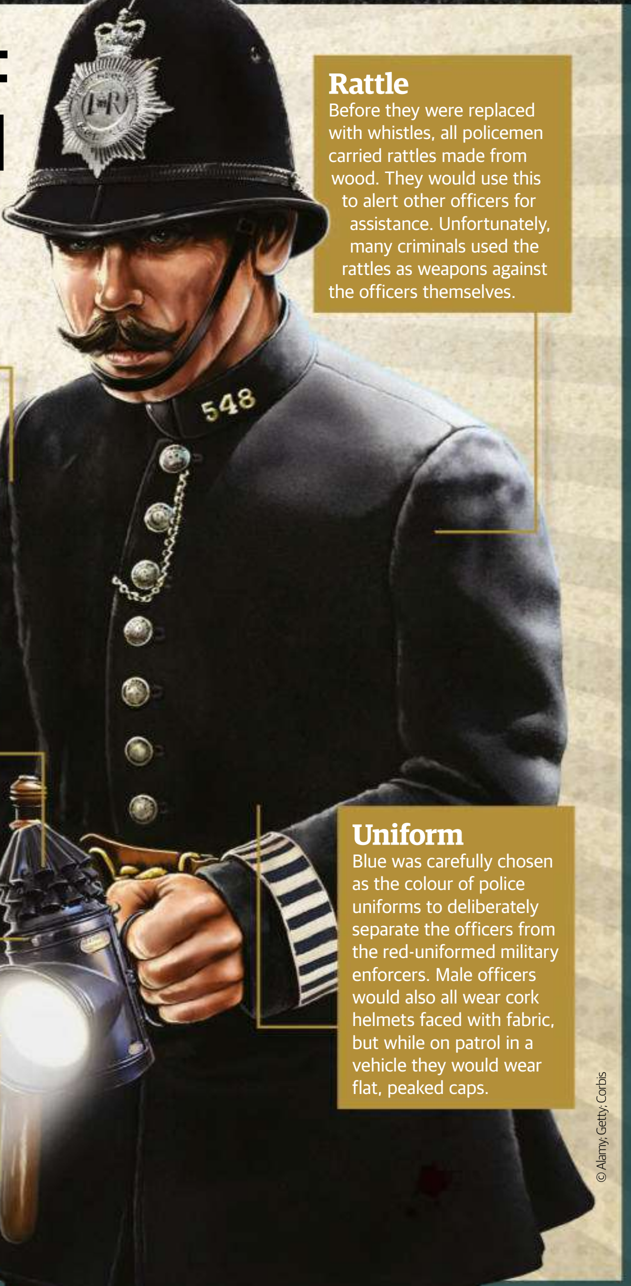
But the cold, bare cells of the gaols were preferable to the grim image of the hangman's noose. Public hangings attracted large crowds up to the day they were outlawed. In one particularly grisly case, the condemned William Bousfield avoided execution by mounting his feet on the sides of the drop. After four more unsuccessful attempts, the hangman leapt into the pit beneath the scaffold and hung on to the prisoner's legs.

Gradually, more liberal ideas were developed, with doctors and psychiatrists interacting with prisoners. However, it would take some time for the authorities to regard criminals as more than an incurable social evil.



For many, the dangers of a life of crime were preferable to being sent to the workhouse

ANATOMY OF A VICTORIAN POLICEMAN



Rattle
Before they were replaced with whistles, all policemen carried rattles made from wood. They would use this to alert other officers for assistance. Unfortunately, many criminals used the rattles as weapons against the officers themselves.

Truncheon
Early truncheons were heavily decorated and seen as proof of identification for the officers. They also featured the monarch's crown and name of the police force. Truncheons were not replaced by identifying warrant cards until the 1890s.

Handcuffs
All policemen were equipped with two pairs of 'D' cuffs, named for the shape that resembled the letter. These handcuffs came in two sizes – one designed for arresting adults and the other in a child-friendly size for young lawbreakers.

Uniform
Blue was carefully chosen as the colour of police uniforms to deliberately separate the officers from the red-uniformed military enforcers. Male officers would also all wear cork helmets faced with fabric, but while on patrol in a vehicle they would wear flat, peaked caps.

Bull's-eye lantern
Due to the lack of streetlights on Victorian streets, officers would carry a lantern to patrol the city at night. The lantern was ignited by lighting a wick resting in an oil-filled container.

© Alamy; Getty; Corbis

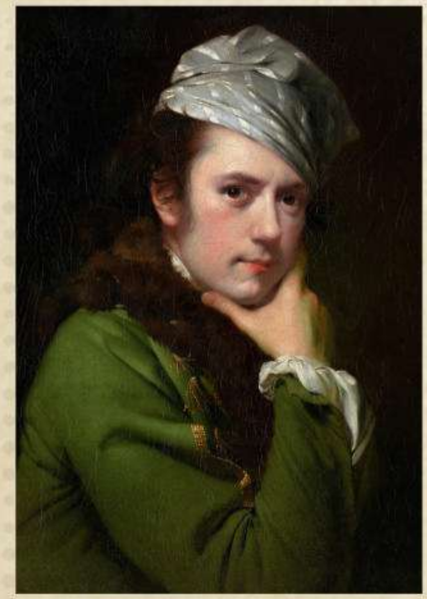
PAINTING PROGRESS:

ART AND CULTURE IN THE INDUSTRIAL AGE

The Industrial Revolution transformed the materials that artists could use – and the way they thought about the world

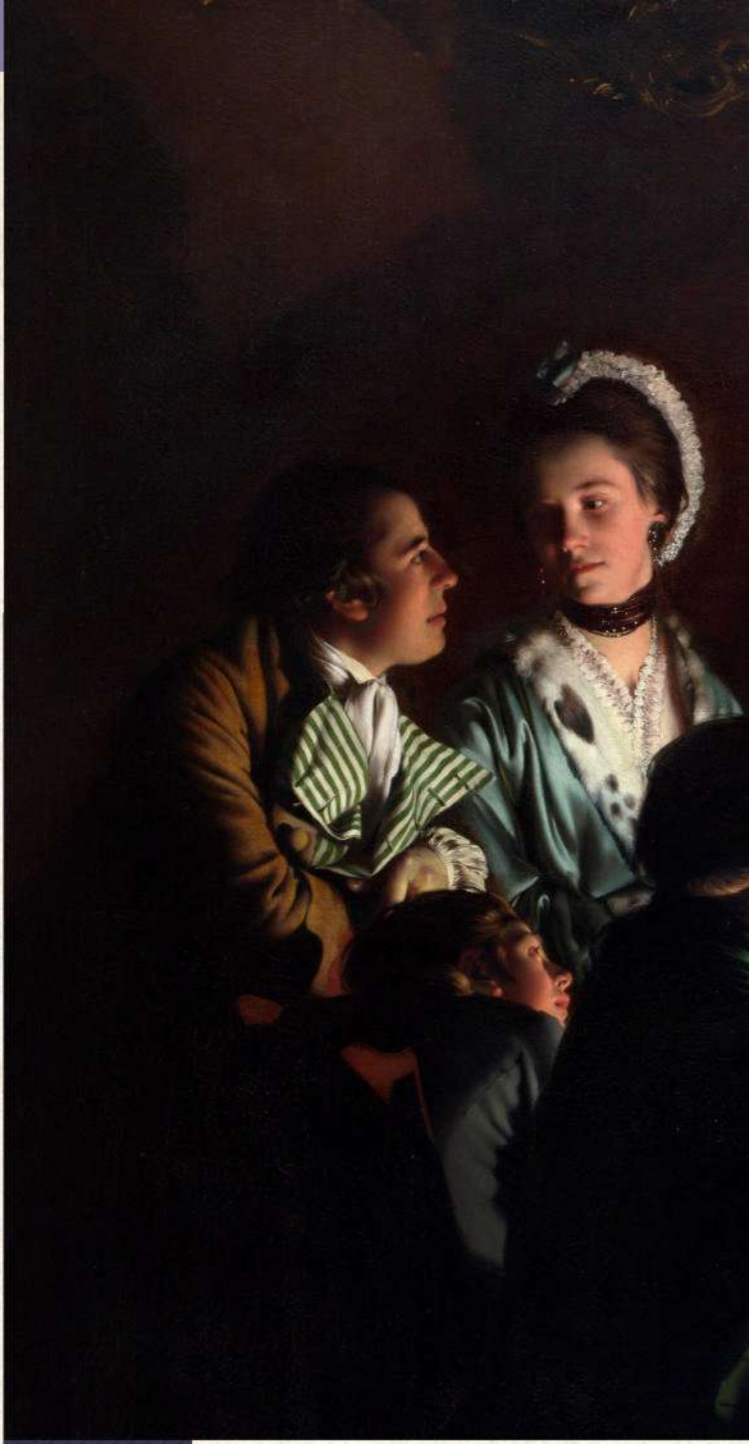
Written by April Madden

Putting down his brush, the painter sighed with satisfaction. The sigh turned into a wheeze; the 34-year-old artist was asthmatic, and the Liverpool air was clotted with smoke. Not even the linseed oil he used to thin his paints into translucent glazes could entirely mask the stench of the noisome air. He would have to consult Doctor Darwin again. He knew what his friend Erasmus would advise: get away from the cities, return to his placid home town in the Derwent Valley. Not that the air there would be any cleaner for very long. Progress was stalking the sleepy country towns of England's Midlands, heralded by the rattle of textile mills and the hellfire scent of industrial kilns. And it was progress that he most wanted to paint, in all its wonderful, terrible glory. That was why he'd taken this chance. His canvas was large, and on it he'd painted a strange, chill, thrilling scene. He didn't have a commission. This was a message more important than money, and he was going to show it to the world at the Society of Artists exhibition that very year.



The year was 1768, and Joseph Wright – known to posterity as Wright of Derby, after the hometown that he returned to in 1777 – was a moderately successful British portrait painter. He'd worked in London and the fashionable resort city of Bath, but his clientele had drawn him northwards again. Unlike some of the more fashionable society portraitists, the gentle, nervous Wright found it difficult to grab the attention of the aristocratic classes. Instead he found his bread-and-butter work painting the nouveau riche of the Industrial Revolution: the owners of factories and potteries and textile mills, and their wives and children. He was affiliated with a group of like-minded intellectual gentlemen called the Lunar Men, named for their habit of meeting on a full moon when travelling by night through the Midlands countryside was easier. The group included Wright's great friend and personal physician, Dr. Erasmus Darwin, pottery founder Josiah Wedgwood, and factory pioneer Richard Arkwright. Their discussions on science, progress, natural history and possibly even alchemy would come to influence Wright's work to such a degree that he would become the painter whose art tells us the most about how the Industrial Revolution was perceived by the people who lived in its crucible. The most famous of his works, both in his lifetime and today, is *An Experiment on a Bird in the Air Pump*, and it's this painting that Wright would finish and exhibit in 1768.

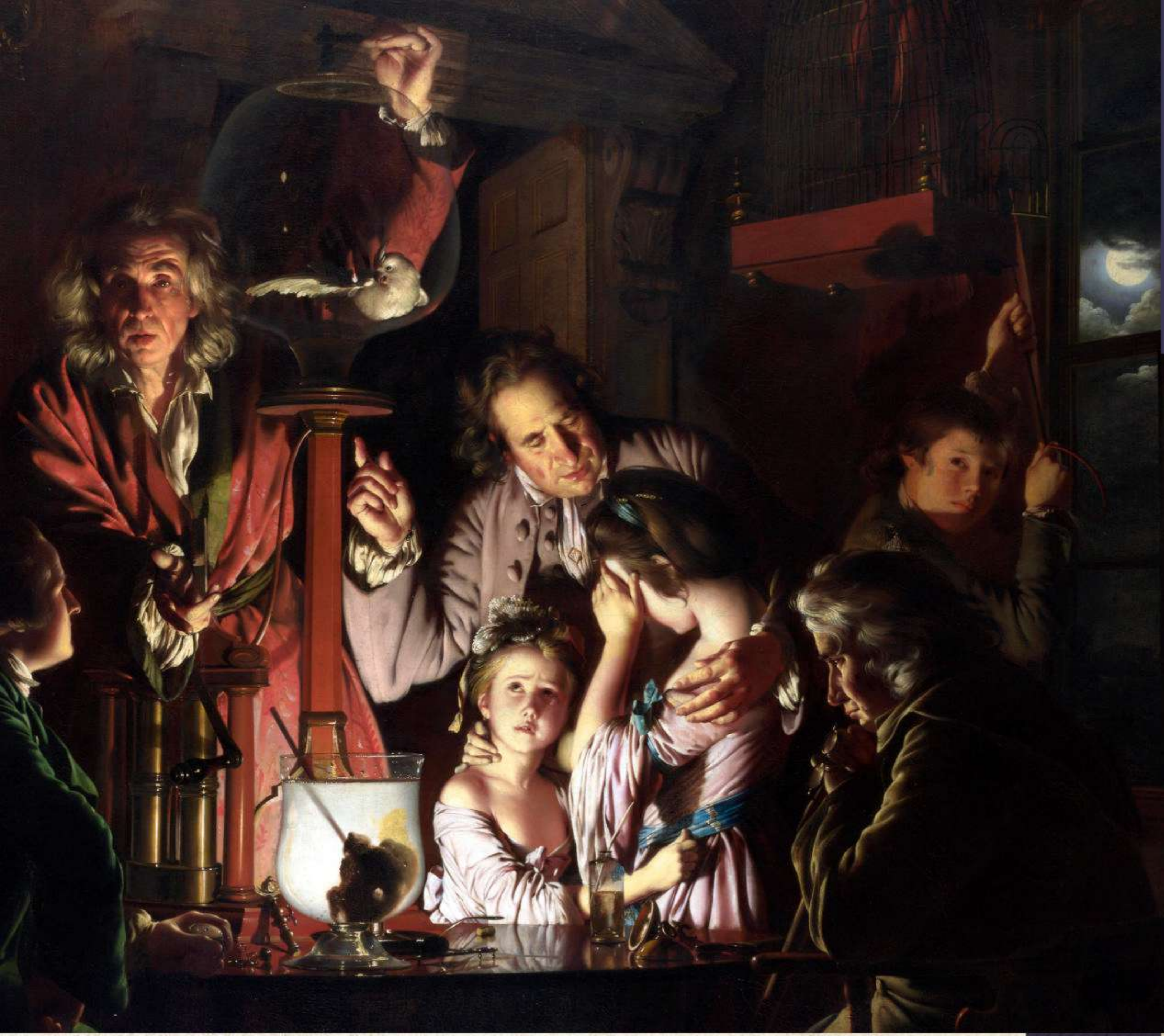
The image is bewildering if you don't know its context. At the top of the



▲ *An Experiment on a Bird in the Air Pump* utilised the iconography of religious paintings to represent science and progress

◄ A self-portrait of Joseph Wright of Derby, created around the same time he painted *An Experiment on a Bird in the Air Pump*

Marshall's
P. M. SOLUTION



The industrialisation of paint production meant that artists' materials were now portable, giving rise to the Impressionist movement that focused on going outdoors to paint from life

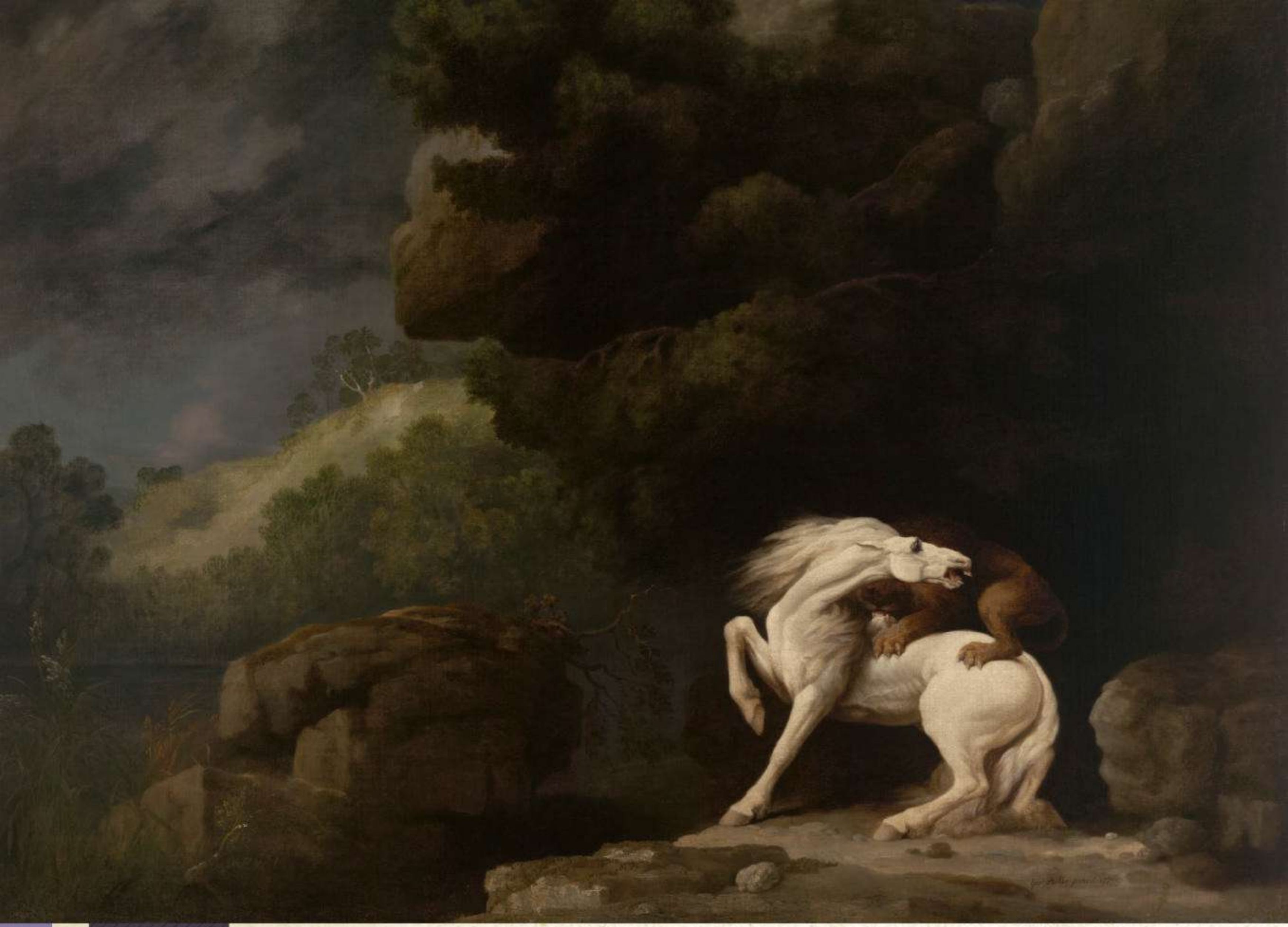
> "AN OLDER GENTLEMAN PONDERS, PERHAPS THINKING OF THE FUTURE AND WHAT SCIENCE LIKE THIS WILL MEAN FOR IT"

composition, an eerie, bewitching figure holds a cockatiel imprisoned in a glass dome. He has overtones of wizardry, and his image would later set the stage for the iconography of today's mad scientist trope. He is in fact a travelling showman who performs not magic tricks in the parlours and drawing rooms of the wealthy but demonstrates scientific experiments.

In this case he uses a pump to suck air out from the cloche the bird languishes beneath, before restoring the poor asphyxiating creature to life once more. On the right, one little girl looks on in horror at her beloved pet while her older sister cries, both comforted by their father, who has clearly seen the experiment before. To the left, a boy and a young man study the experiment eagerly, flanked by a pair of lovers who are too wrapped up in each other to notice what's going on.

In the foreground, an older gentleman ponders, perhaps thinking of the future and what science like this will mean for it. He is seated next to a jar containing a disfigured human skull – both an exhibit that the showman would have presented and an artistic motif called a memento mori to tell us that this painting deals with death and the human condition.

In the background the showman's sly-eyed assistant raises a blind, revealing



While Wright was painting science, his contemporaries were painting dramatic scenes in unspoiled landscapes. However, artist George Stubbs did revolutionise the scientific study of equine anatomy through dissection and also drawing

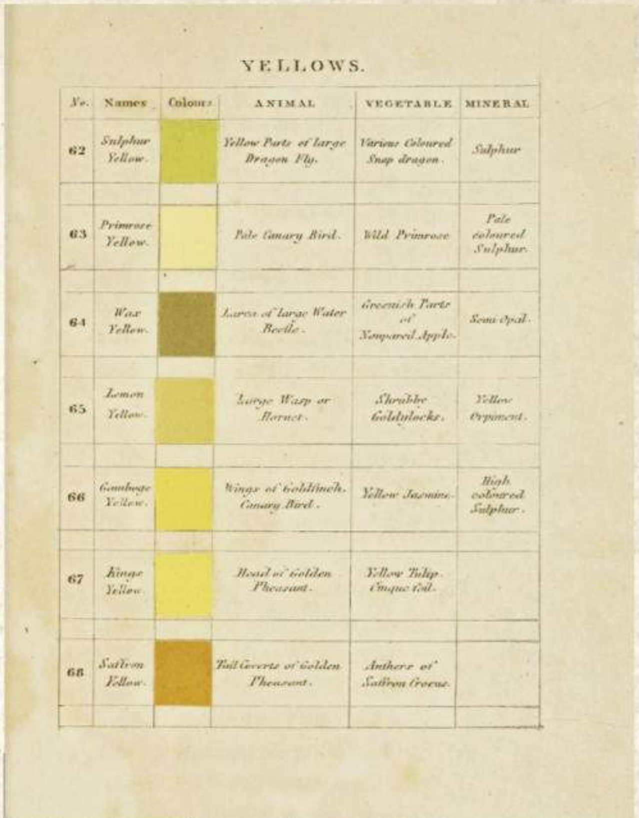
In *Rain Steam and Speed – The Great Western Railway*, JMW Turner alludes to the speed of industrialisation. The hare running away from the steam engine is now largely invisible due to light degradation

a full moon in a nod to Wright's friends in the Lunar Men. The moon is not the painting's main light source; that is supplied from the candles that illuminate the scene at the table. But the way Wright has lit the scene is very interesting – it's the lighting style that Renaissance painters would use to portray the birth of Christ. Wright is telling us with this 'Nativity light' that we are witnessing the birth of a new deity, one that has power over life and death and the ability to heal disease. But this deity isn't the usual supernatural god. It's science, progress – the beating heart and animating force of the Industrial Revolution.

Not all artists were as interested as Wright in the cultural significance of this brave new world – in fact, in the face of it many retreated towards idealised imagery of the natural world instead. The Romantic genre of the late 18th century is full of beautiful people cavorting amid pastoral scenes, or of stirring, dramatic events taking place on storm-riven peaks. Many subjects were taken from classical or medieval history and invoke the idyllic concept of a golden age long before science or progress came to mar the landscape with their filthy mills and factories. Yet it was those factories that enabled artists to encapsulate their vision like never before, because it was during the Industrial Revolution that the production of paints was first industrialised and standardised.

Before this time many painters had to have a working knowledge of chemistry – or rather of alchemy as it was back then. Not all were men of science like the polymath Leonardo da Vinci, but they needed to know enough to mix their own paints, out of earth pigments, metals, oil, egg and a variety of other strange and sometimes arcane substances. Many apprentices in artists' studios started out doing this before they were ever let near a canvas, and unless they were literate, neat-handed, sharp-eyed and working in consistent lighting conditions, the colours they mixed could vary wildly from day to day. Some of the rare substances used for creating particular colours were unavailable outside of their local area, only came into season at certain times of year (and could be affected by climatic events like drought or rainfall), or their sale was restricted and heavily monopolised; others were dangerous to work with. This limited the colours that artists had available to them, resulting in homogenous and sometimes dull colour palettes – the drab neutrals available cheaply in the medieval Netherlands couldn't compete with the vivid roses and blues that were more easily obtained in Italy. Industrial paint manufacture

"IT WAS DURING THE INDUSTRIAL REVOLUTION THAT THE PRODUCTION OF PAINTS WAS FIRST INDUSTRIALISED AND STANDARDISED" changed all that. Not only did it make vivid, iconic colours like Ultramarine easy to obtain across Europe, it packaged them in neat little tubes, meaning for the first time a painting kit was truly portable. At the height of the Industrial Revolution the French Impressionists encouraged each other outside to paint in fields and woods – 'en plein air', they called it – to capture their impressions of light on water and foliage. With established artists no longer requiring a studio of colour-mixing skivvies to whip up their paints, these young would-be artists tumbled gleefully outside, paintbrushes in hand, to begin their painting careers far earlier than their predecessors had done.

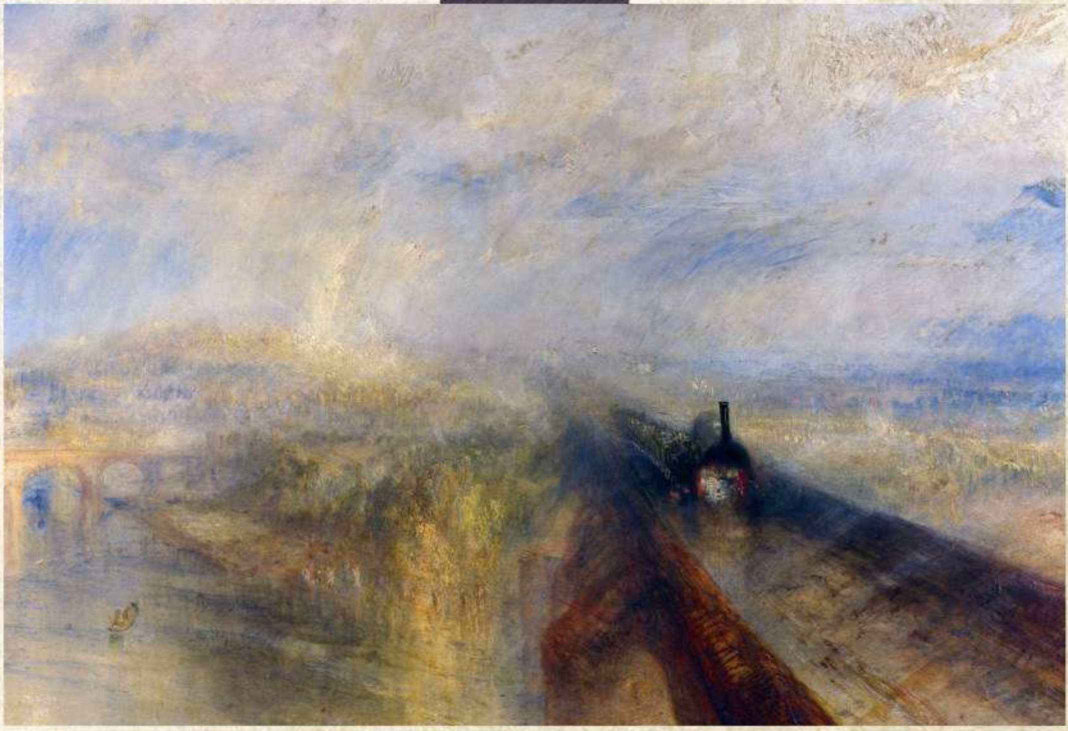


YELLOWS.

No.	Names	Colours	ANIMAL	VEGETABLE	MINERAL
62	*Sulphur Yellow.*	🟨	*Yellow Parts of large Dragon Fly.*	*Various Coloured Snap dragon.*	*Sulphur*
63	*Primrose Yellow.*	🟨	*Pale Canary Bird.*	*Wild Primrose*	*Pale coloured Sulphur.*
64	*Wax Yellow.*	🟫	*Larva of large Water Beetle.*	*Greenish Parts of Nonpareil Apple.*	*Semi Opal.*
65	*Lemon Yellow.*	🟨	*Large Wasp or Hornet.*	*Shrubby Goldylocks.*	*Yellow Orpiment.*
66	*Gamboge Yellow.*	🟨	*Wings of Goldfinch. Canary Bird.*	*Yellow Jasmine.*	*High coloured Sulphur.*
67	*Kings Yellow.*	🟨	*Head of Golden Pheasant.*	*Yellow Tulip. Cinque foil.*	
68	*Saffron Yellow.*	🟧	*Tail Coverts of Golden Pheasant.*	*Anthers of Saffron Crocus.*	

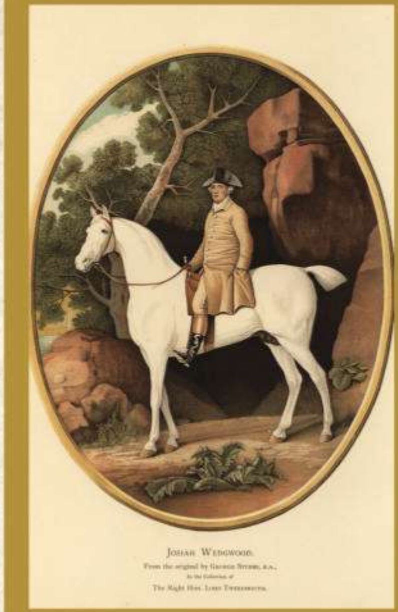
▲ Before the advent of industrial paint manufacture artists had to mix colours by hand. *Werner's Nomenclature of Colours* was a visual guide to colours from the natural world

Seventy-six years after Joseph Wright painted the crucible of the Industrial Revolution as a mystical, magical Nativity scene, another British artist would return to pondering it. JMW Turner was famed for his nautical scenes, landscapes, and for his love of the fiery (polluted) skies above them. He was fond of painting out of doors along the banks of the Thames and on the bridges of London, and the new pigment manufacture methods meant he was able to do so (sadly the less lightfast paints of the time also mean that Turner's work is fading fast and needs constant monitoring and conservation). In *Rain, Steam and Speed – The Great Western Railway*, Turner depicts a new titan of the Industrial Revolution going about its terrible business: an early rail locomotive. As it crosses the bridge from the present into the future, the steam train bears down on a running hare (now almost invisible due to light degradation), traditionally symbolic of fear, vulnerability, and of the moon that illuminated Wright's work nearly a century before. Despite how the Industrial Revolution had transformed the kind of painting that Turner was able to do, the message of this painting is clear: Britain's fastest native animal has no hope of outrunning the iron sinews of progress as they charge inexorably onward. It is the hunter, and the idyllic pastoral scenes the Romantic artists dream of are the hunted.



A MAN AND A BROTHER

How Josiah Wedgwood embraced the industrial process and mass production to build a pottery empire

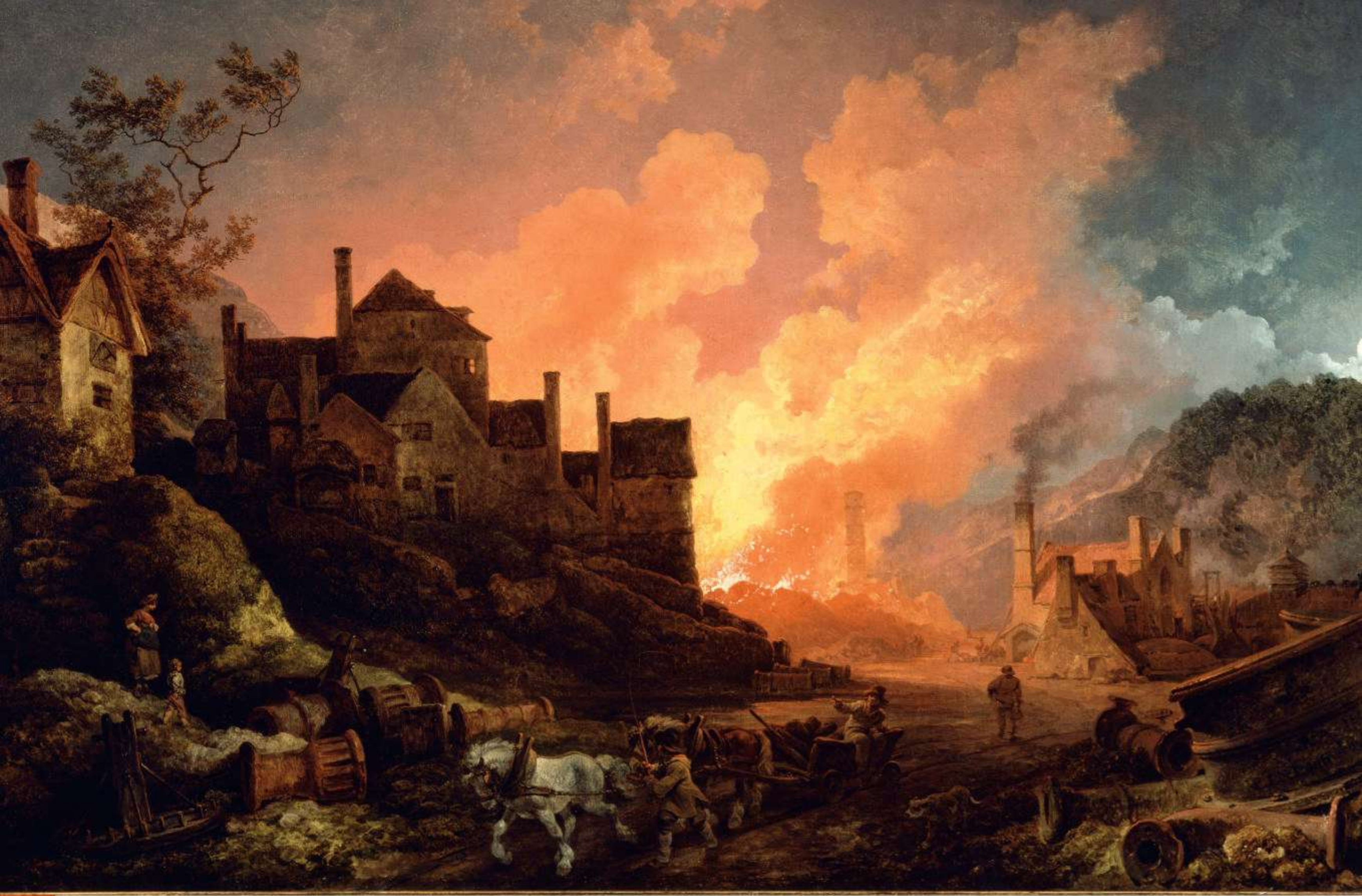

Josiah Wedgwood.

Josiah Wedgwood was a friend of Joseph Wright and affiliated with the same Lunar Men group of middle class, working intellectuals. We know Wedgwood today for the pottery brand that still bears his name, famous for its examples of 18th-century Neoclassical design and for the beautiful opaque blue and green glazes that Josiah made his name as a journeyman potter with. Prone to knee injuries after a childhood bout of smallpox, he concentrated on ceramic chemistry and industrial processes during his early career due to his inability to consistently work the pedal of a potter's wheel.

Wedgwood never made porcelain, or bone china, in Josiah's lifetime (the European quest for the secrets of Chinese pottery is a bizarre story involving an alchemist held hostage in a German castle). Instead, like other British potteries, he concentrated on the heavier and more solid stoneware and was responsible for industrialising its manufacture and leading the charge in the creation of mass production. Wedgwood produced both expensive artisanal ware for wealthy clients and cheap mass-produced versions for the less well-off, allowing ordinary working people to enjoy the latest aesthetic trends in home decor. These cheaper mass-made products used industrial moulding instead of potter's wheels and transfer-printing instead of hand-painting.

Josiah also created postal catalogues to sell his wares and invented sales incentives, including buy-one-get-one-free, the money-back guarantee, and free delivery. One of his most famous works was an anti-slavery medallion bearing the slogan "Am I not a man and a brother?" His scientific interests continued to run in the family; he and fellow Lunar Man Erasmus Darwin were the grandfathers of scientist Charles Darwin, the 'Father of Evolution'.

© Alamy, Getty



The beautiful depiction of Britain's shifting countryside shown above features on the cover of David Stacey's book

Main image: © Board of Trustees of the Science Museum

A BRUSH WITH CHANGE

How seven artists depicted an era of seismic technological transformation in Britain

Between 1750 and 1830, Britain underwent an unprecedented period of change that saw it move from an agricultural society to the modern industrial country we know today. The Industrial Revolution saw the British economy transformed by new materials such as iron and steel, the growing use of fossil fuels, the introduction of factories and cutting-edge machinery, and a mass migration from the countryside to the rapidly swelling cities.

Somewhat surprisingly, while this period was discussed heavily in literature (notably the works of Charles Dickens) and featured in sketches, few paintings remain. A 2021 book from Oxford University Press, *Art and Industry* by David Stacey, details the work of seven artists of the era and places them in the context of their time. The artists featured are: Joseph Wright of Derby (1734–97), John Opie (1761–1807), Philippe-Jacques de Loutherbourg (1740–1812), Penry Williams (1802–85), William Havell (1782–1857), Joseph Mallord William Turner (1775–1851) and Henry Hawkins (1800–81).

In his book, Stacey convincingly argues that these artists portray, in their own individual ways, the various problems and conditions that arose during the Industrial Revolution. Thematically they show a coherent approach to changing technologies, industries and social classes within 18th- and 19th-century Britain.

> **"THESE ARTISTS PORTRAY THE PROBLEMS AND CONDITIONS THAT AROSE DURING THE REVOLUTION"**

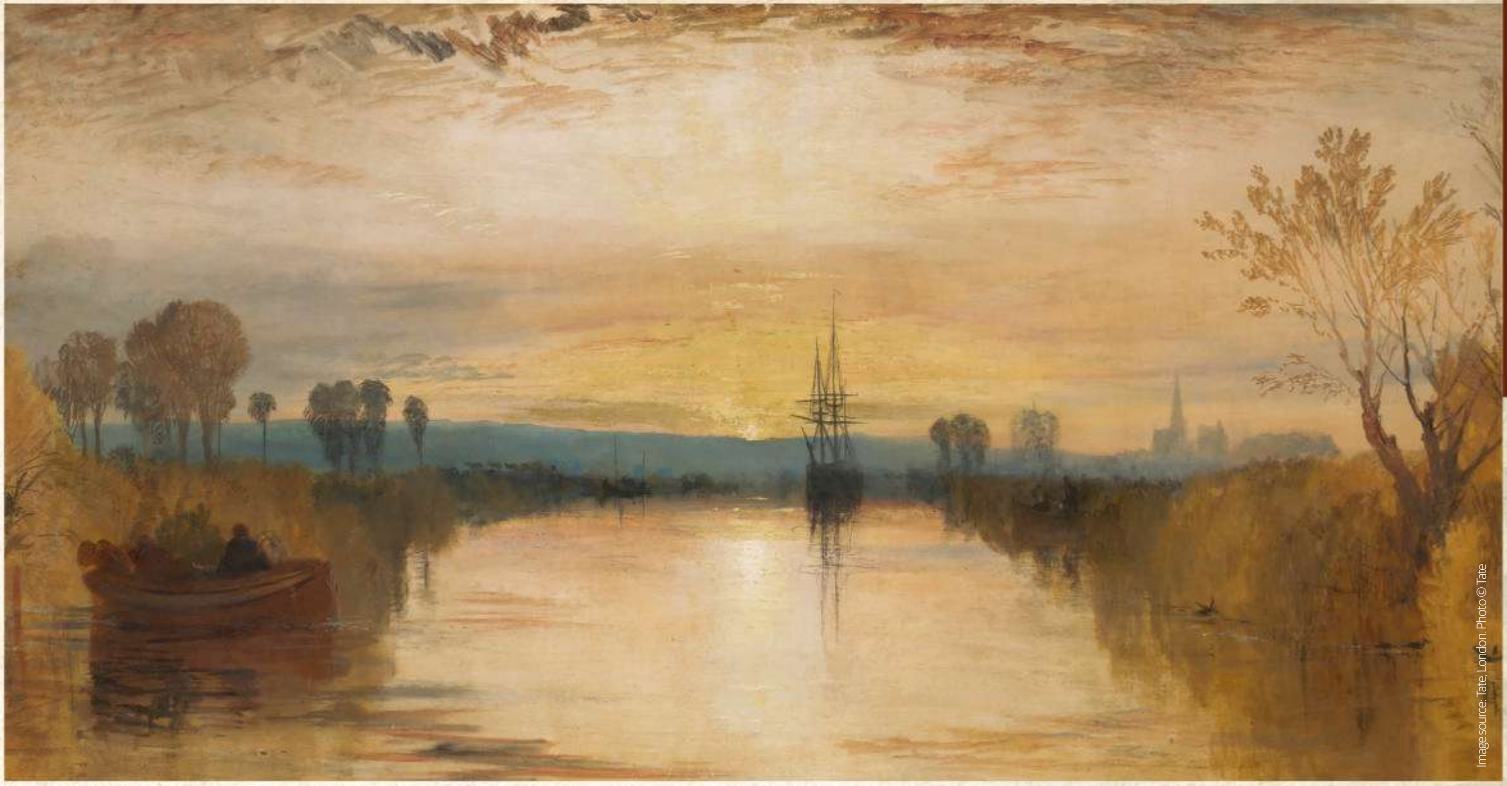


Image source: Tate, London Photo © Tate

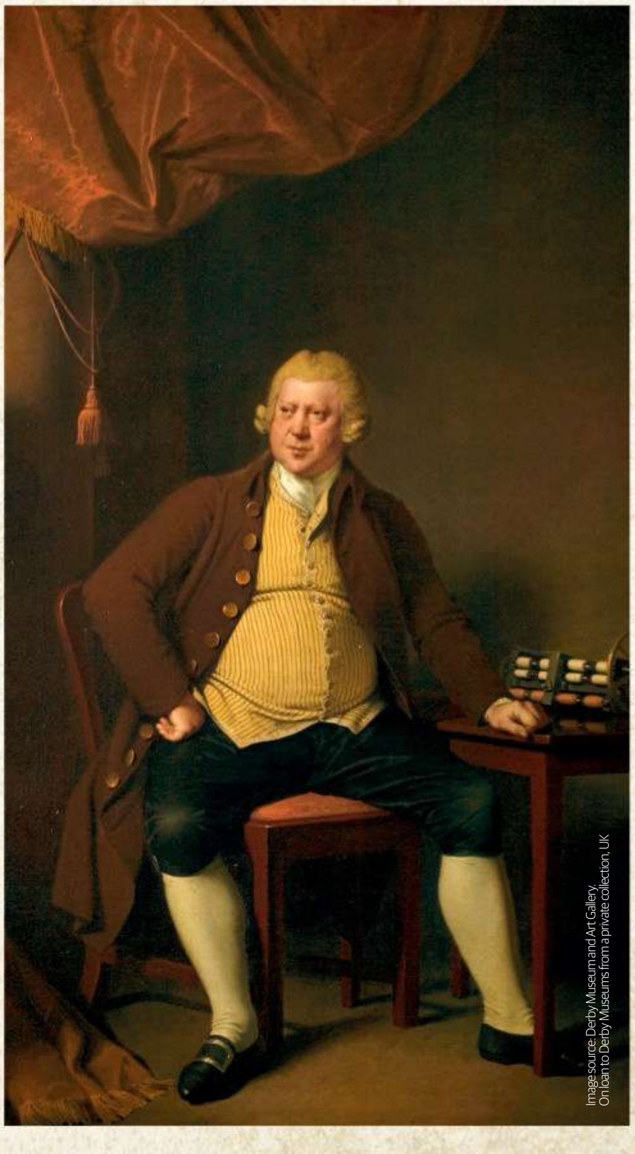


Image source: Derby Museum and Art Gallery. On loan to Derby Museums from a private collection, UK

SIR RICHARD ARKWRIGHT

1732–92

This painting of entrepreneur Richard Arkwright by Joseph Wright of Derby shows him seated next to a model of his patented spinning frame. The first water-powered spinning frame, its invention ensured Arkwright would be remembered as one of the founders of the factory age.

CHICHESTER CANAL

Joseph Mallord William Turner remains a beloved painter of the Romantic period, nicknamed 'the painter of light' due to his distinctive use of colours. Shown here is a painting of Chichester Canal, one of a series from the 1790s–1830s in which Turner portrayed Britain's emerging canal infrastructure.

ARKWRIGHT COTTON MILLS BY NIGHT

A night vista of Richard Arkwright's cotton mill complex in Cromford, Derbyshire. By 1780, it employed over 600 men, women and children. So successful was Arkwright's spinning mill design he was able to sell them as far afield as America.

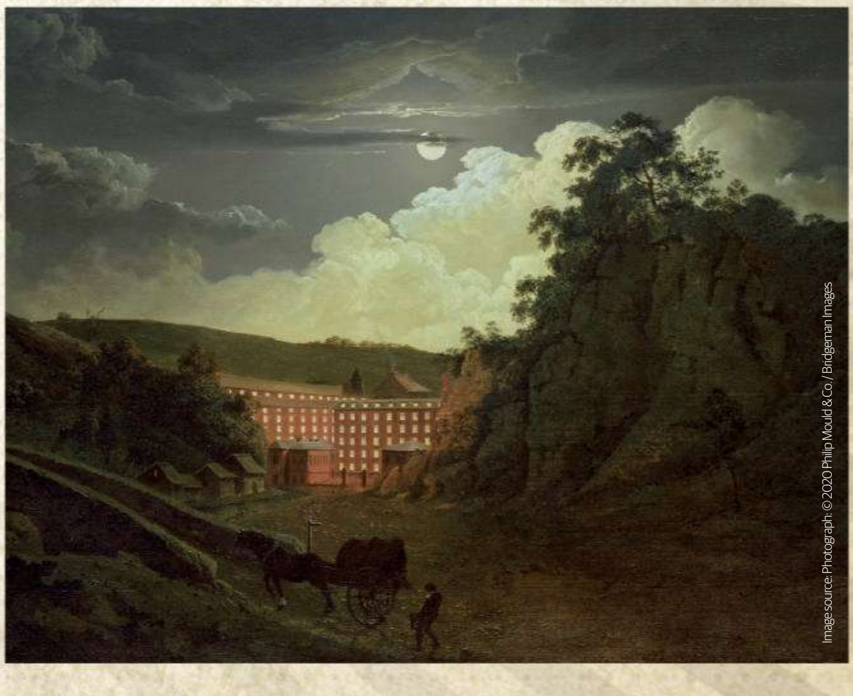
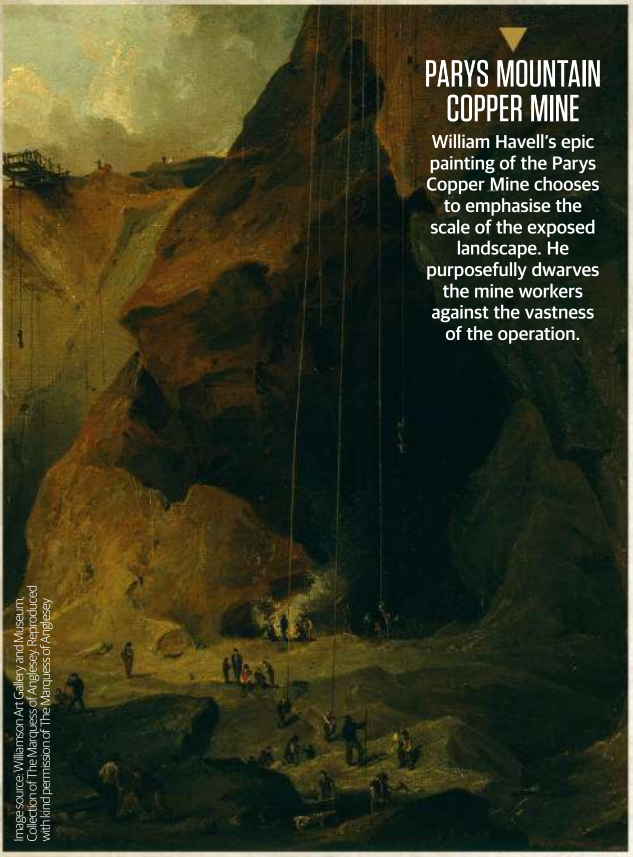


Image source: Photograph © 2020 Philip Mould & Co. / Bridgeman Images



PARYS MOUNTAIN COPPER MINE

William Havell's epic painting of the Parys Copper Mine chooses to emphasise the scale of the exposed landscape. He purposefully dwarves the mine workers against the vastness of the operation.

Image source: Williamson Art Gallery and Museum, Collection of The Marquess of Anglesey. Reproduced with kind permission of The Marquess of Anglesey

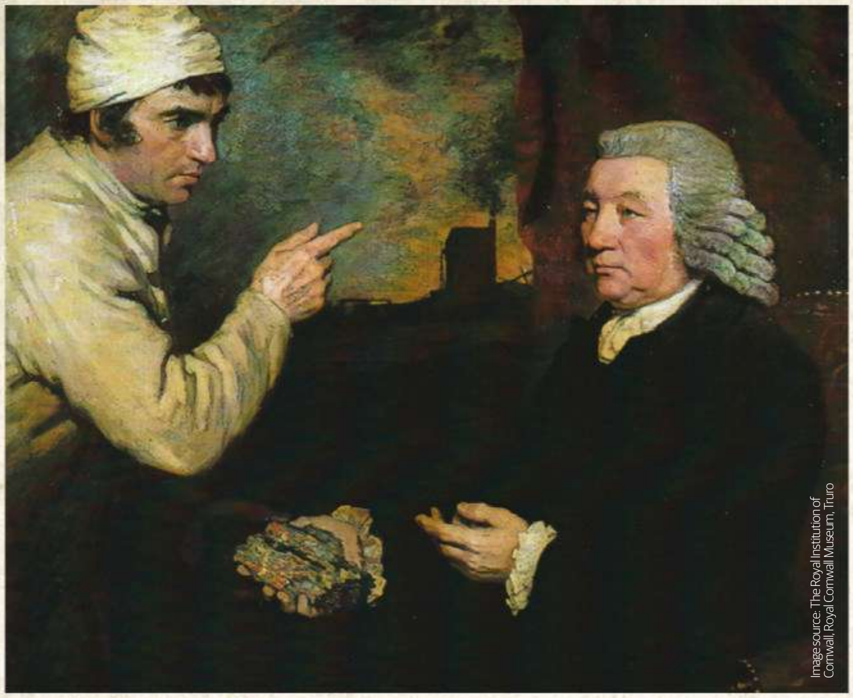
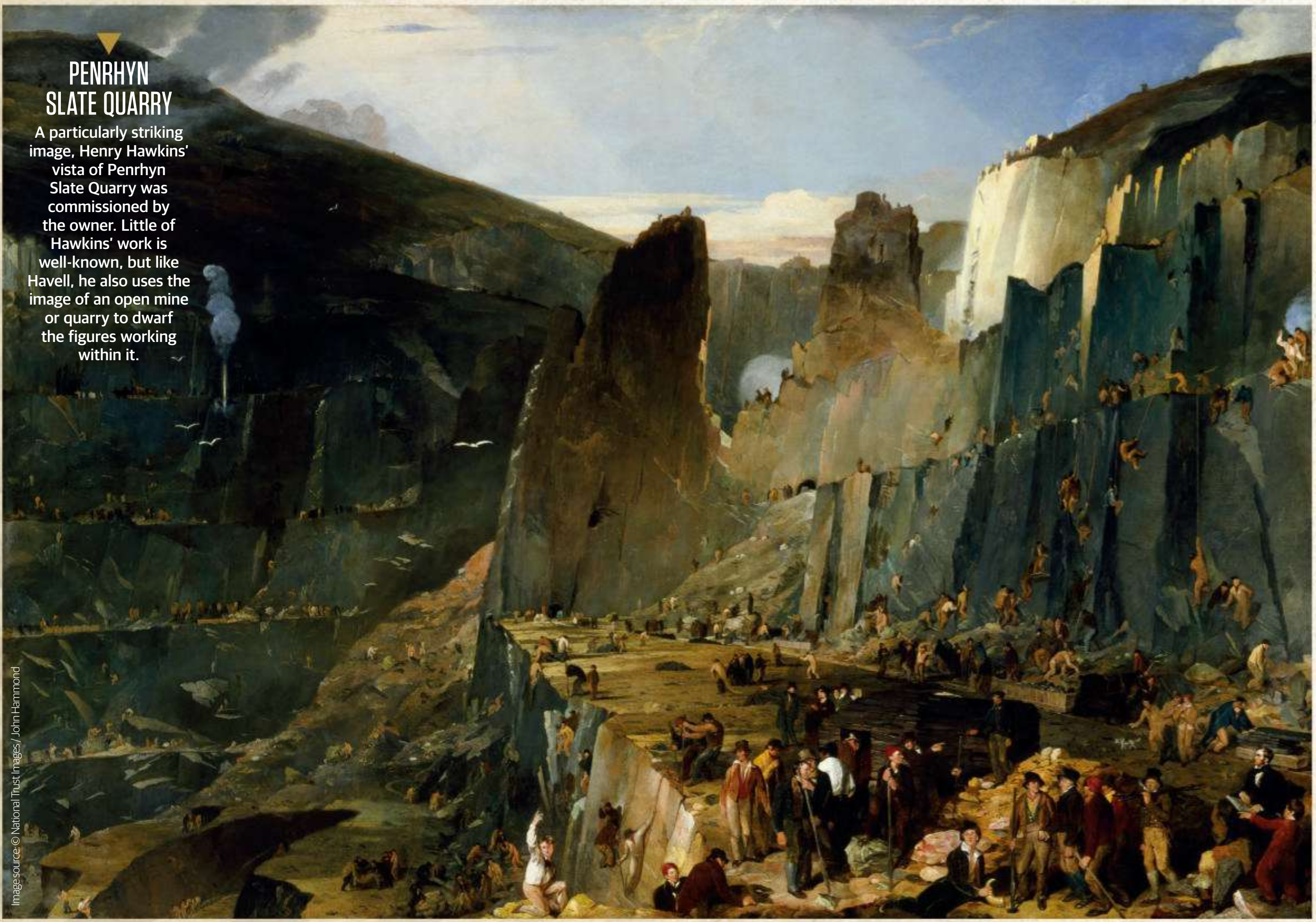


Image source: The Royal Institution of Cornwall, Royal Cornwall Museum, Truro

A GENTLEMAN AND A MINER

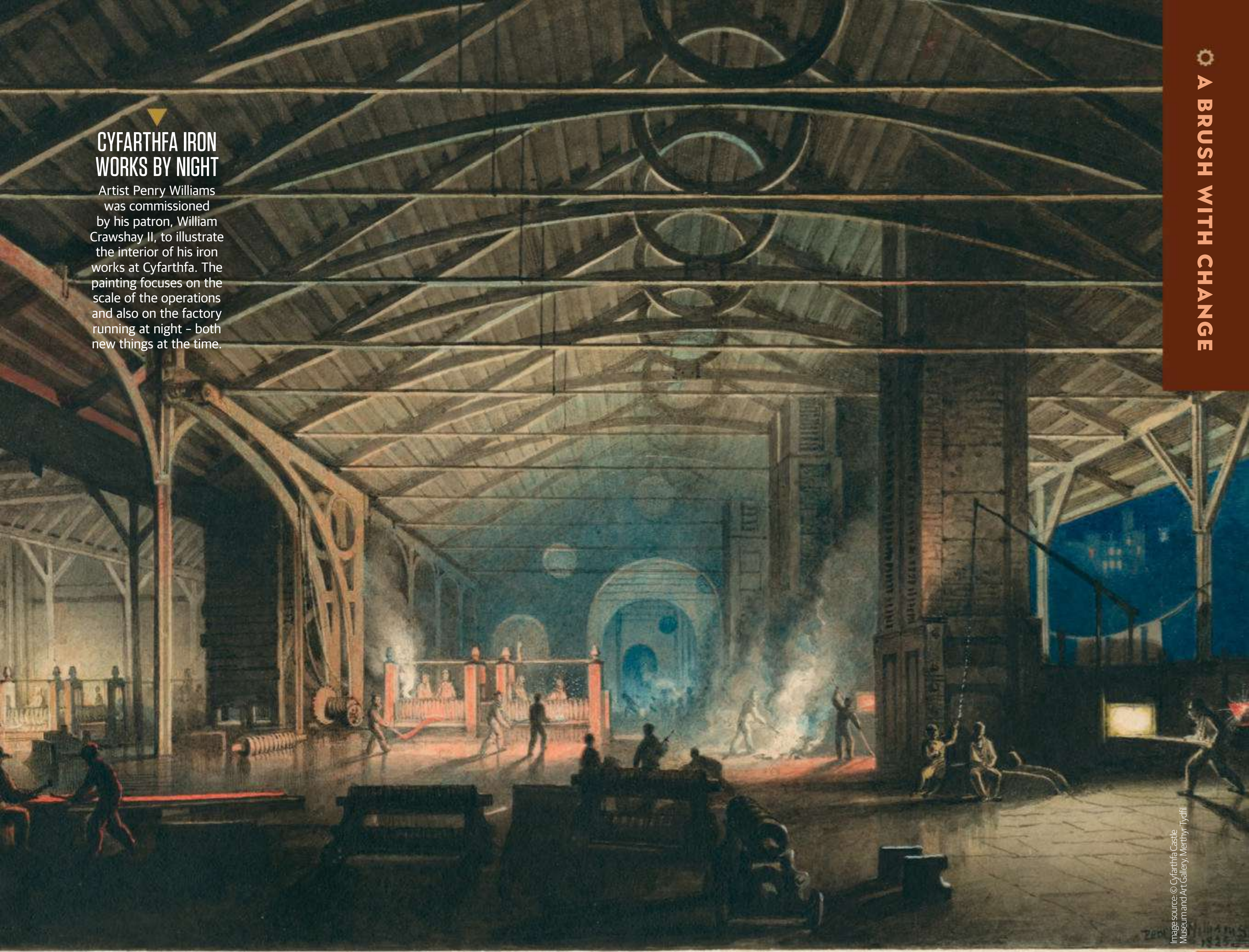
Joseph Opie's painting *A Gentleman and a Miner* is a highly unusual and politicised painting for the time. Stacey argues the placement of the figures, both literally and metaphorically, gives the miner the upper hand, drawing attention to some of the inequalities in mining at the time.



PENRHYN SLATE QUARRY

A particularly striking image, Henry Hawkins' vista of Penrhyn Slate Quarry was commissioned by the owner. Little of Hawkins' work is well-known, but like Havell, he also uses the image of an open mine or quarry to dwarf the figures working within it.

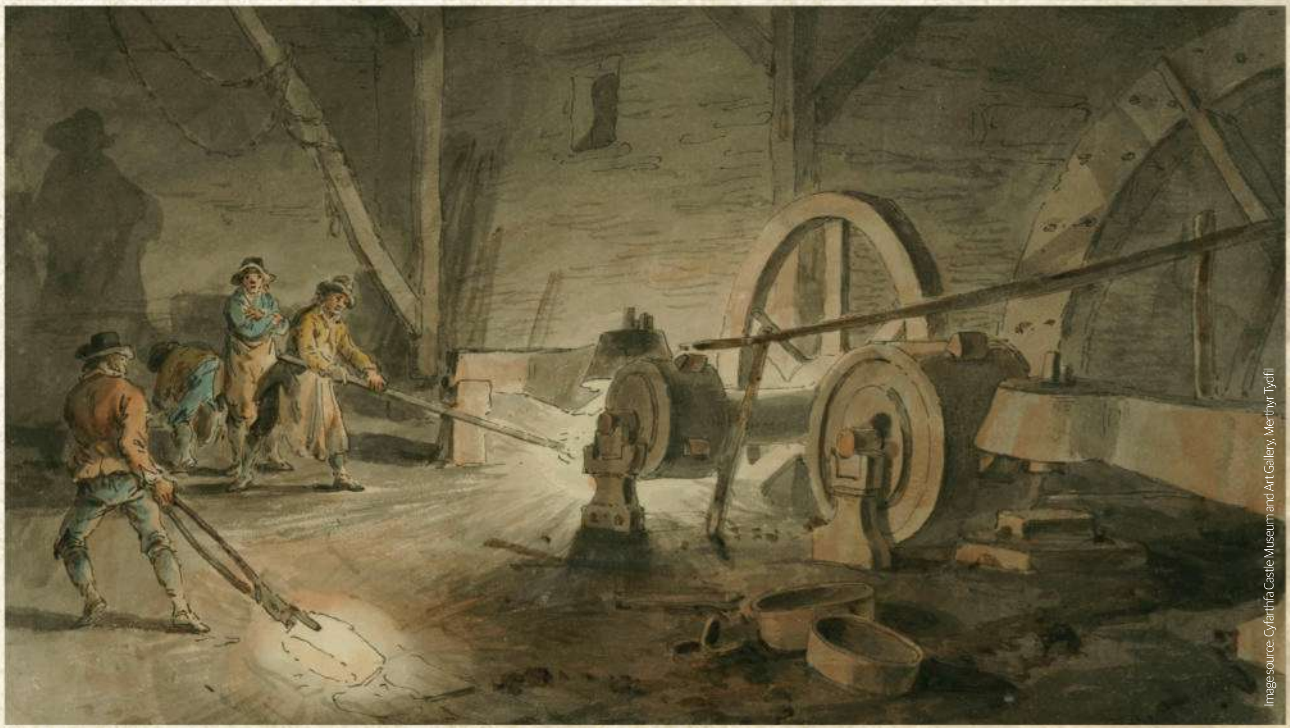
Image source: © National Trust Images / John Hammond



CYFARTHFA IRON WORKS BY NIGHT

Artist Penry Williams was commissioned by his patron, William Crawshay II, to illustrate the interior of his iron works at Cyfarthfa. The painting focuses on the scale of the operations and also on the factory running at night – both new things at the time.

Image source: © Cyfarthfa Castle Museum and Art Gallery, Merthyr Tydfil



AN IRON FORGE AT MERTHYR TYDFIL

By the 1850s, Merthyr Tydfil had expanded from a small village to one of the largest towns in Wales, renowned for its ironworks. At the time the town was responsible for 40 per cent of Britain's iron exports and pioneered new methods that significantly increased production rates.

Image source: Cyfarthfa Castle Museum and Art Gallery, Merthyr Tydfil

STITCH UP:

FASHION OF THE INDUSTRIAL REVOLUTION

While industry was changing, so was the contents of the population's wardrobes

Written by Alex Hennessy

Standing before his tailor in a tastefully decorated room, an English gentleman of the early 1700s might be measured for a coat of fine wool or silk. To sit underneath it, he might choose a waistcoat embroidered with threads of silver and bright colours. These, paired with breeches in a coordinating colour, and a shirt of fine muslin or cambric cloth, would make a perfect outfit for many a high-society occasion.

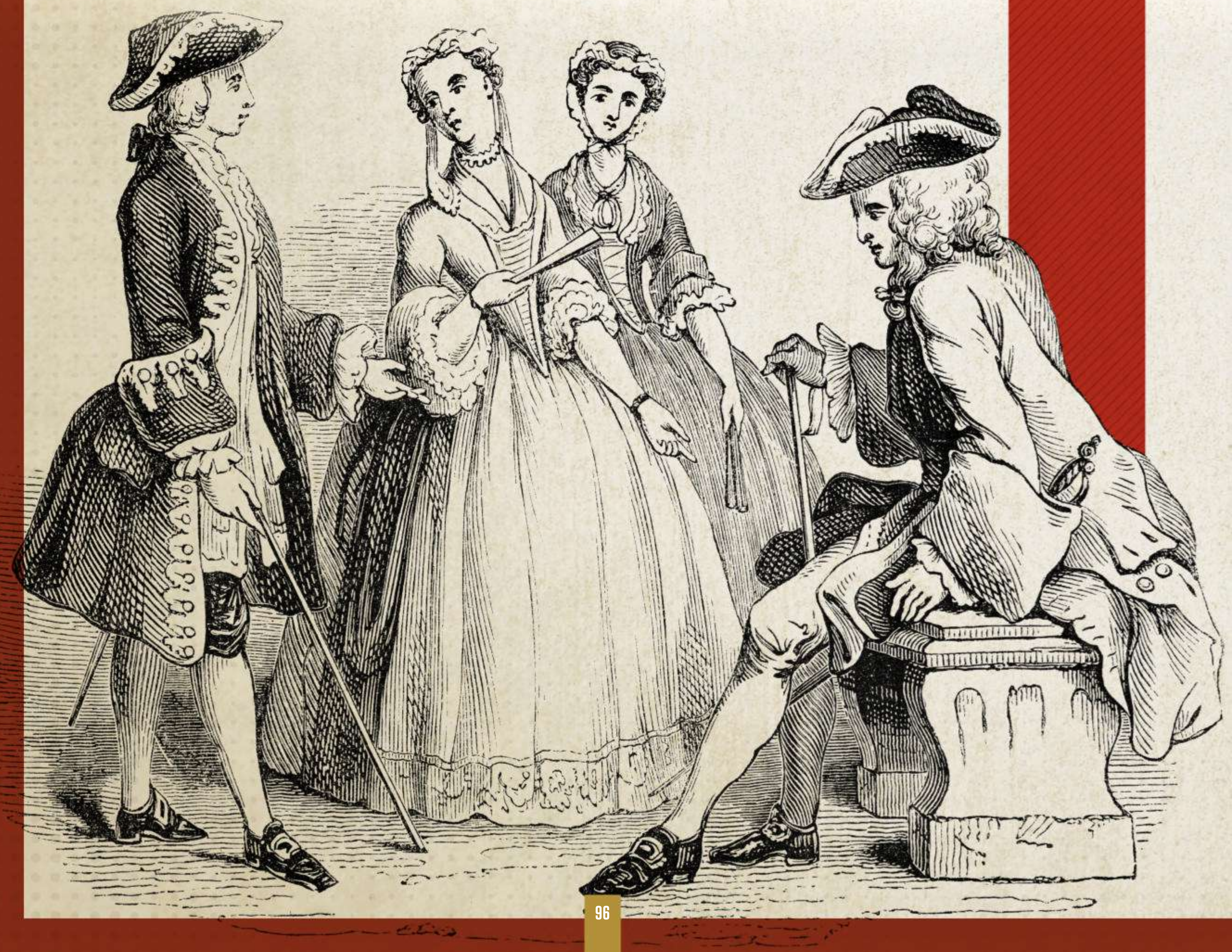
A working man, however, wore far more modest clothing. His wardrobe would consist of no more than a handful of outfits. The components would be the same: a shirt, waistcoat, breeches and coat, but the fabrics were coarser. Flax and hemp were woven for shirts, while the coat might be crafted from a heavier flannel or wool worsted.

One common characteristic did link both men's outfits: each piece was handmade because there was no alternative. Yarn was hand-spun by rural people, often families, then woven with a handloom. Shirt-making was a domestic task that fell to women. But, as with so many aspects of life leading up to the Industrial Revolution, this was all to change - and soon.

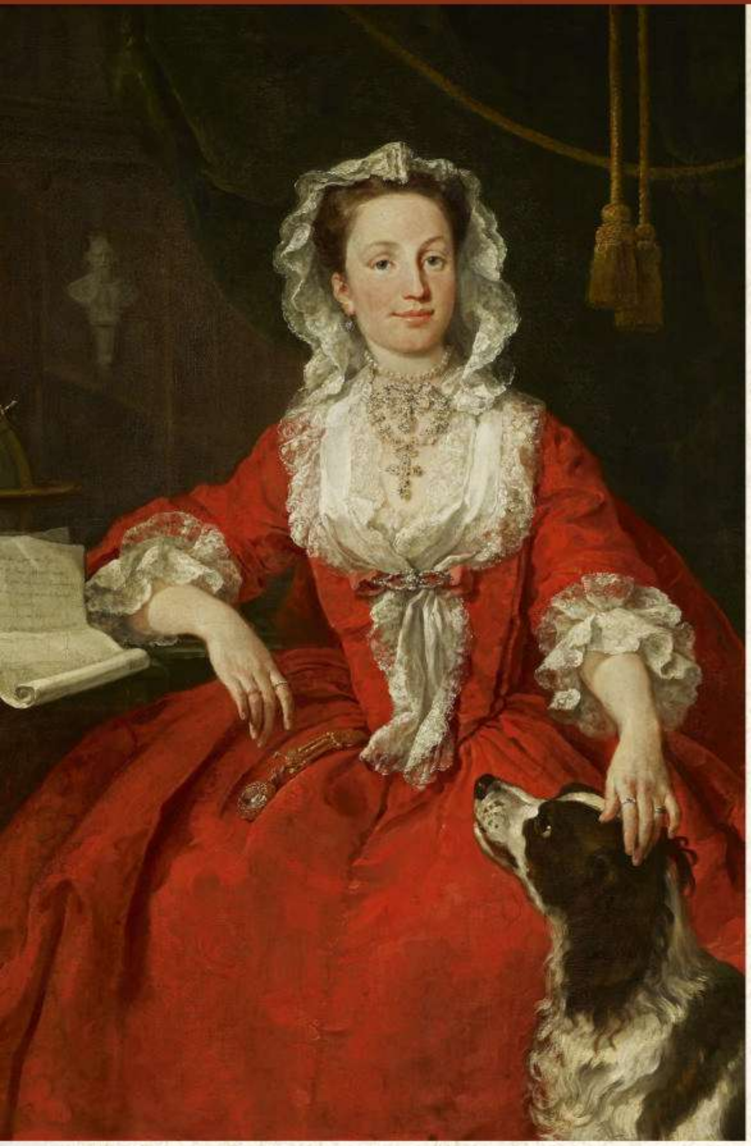
A raft of inventions would make the process of spinning and weaving fabrics more efficient. First, the flying

► Miss Mary Edwards, painted by William Hogarth in 1742. Her ruffled dress exemplifies Rococo style

▲ The spinning mule was dangerous, and children were often employed to work with it



▼ When materials became more affordable to all, the upper classes looked for new styles to make sure they still stood out



shuttle, invented in 1733 by John Kay of Lancashire. Kay added wheels to the shuttle, a part of the loom that, until then, had to be passed through the threads by hand. This relatively simple change made weaving faster and simpler. Then came the spinning jenny, invented by James Hargreaves in 1764. This put paid to hand-spinning yarns one by one, as it could spin 50 strands of yarn at a time.

Another Lancashire man, Richard Arkwright, invented the water frame in 1769. This used water power to straighten out cotton and twist it together – key parts of the yarn-spinning process. Perhaps most impressive of all was the spinning mule, invented by Samuel Crompton in 1779. Where the spinning jenny had increased the number of yarns a person could spin to eight, the spinning mule propelled this into the hundreds. Not only could it produce more yarn at once but the yarn was better quality. It became the most-used textile machine in Lancashire, which, by the late 18th century, was a hub for mechanised textile manufacture.

In 1785, Edmund Cartwright patented the power loom, a machine that built upon Arkwright's water frame and automated textile weaving even further. As production power increased, a fierce demand for cotton emerged, and in 1793 Eli Whitney invented the cotton gin in America. This machine sped up the removal of seeds from the cotton fibre so that it could be sold and shipped to Britain more quickly. Unfortunately, its efficiencies and the opportunities for subsequent wealth encouraged landowners in southern America to grow cotton almost exclusively. To do this, they had to rely on the work of slaves. By the 1780s, a large proportion of the cotton used in Manchester's factories had been grown by enslaved people in America and the Caribbean.

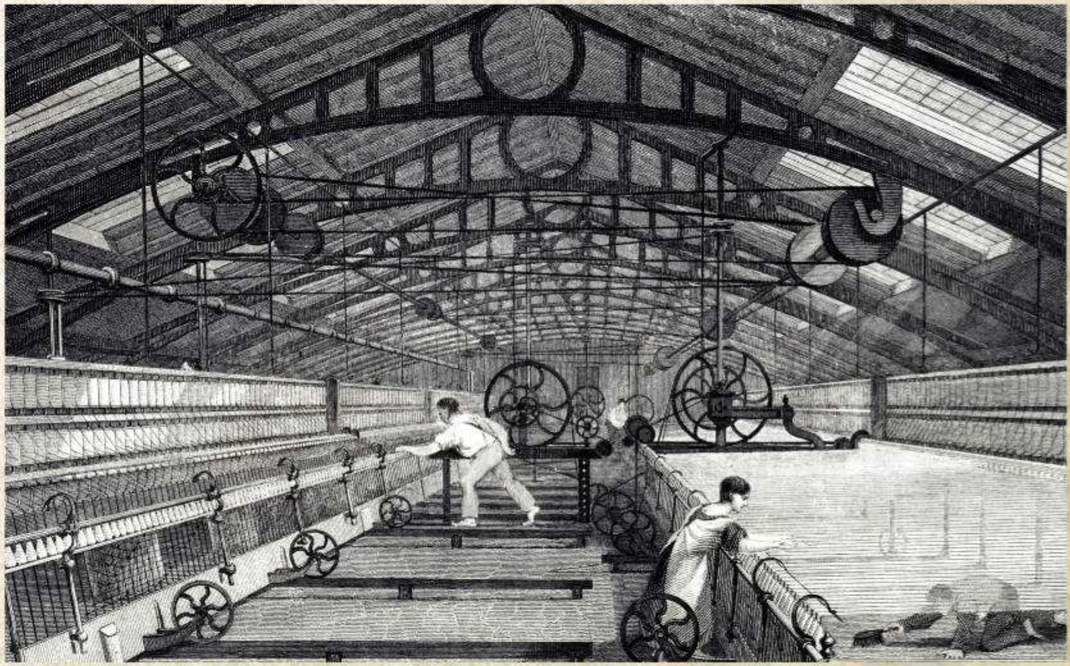
In the span of 60 years the efficiency of textile production had skyrocketed. But what effect did this have on the clothes worn by the people of England? The differences between the clothing of the upper and lower classes began to shrink. Muslin, previously reserved for the shirts and dresses of the upper classes, became available to all by 1815. Working-class families could buy clothes from travelling salesmen or local clothing businesses. Those in large cities might even browse a whole street of shops selling new and used clothing, such as Monmouth Street in London. From as early as the 1760s it was unusual for even working class people to make their own clothes.

Among those who could afford it, the services of tailors and seamstresses were still in high demand. The upper classes could now choose from more colours and styles of fabrics, and trends changed far more rapidly, particularly in women's fashion. But with better fabrics now available to the lower classes, the upper classes sought new fashions in order to distinguish themselves. This often involved taking inspiration from continental Europe, for example the Rococo style, which originated in France in the 1720s and remained in fashion until the 1770s. It was highly decorative, bringing an abundance of ruffles, patterns, bows and voluminous fabrics not only to clothing but interiors too.

The first sewing machine wouldn't be invented until 1830, but it too would bring about change. Barthélemy Thimonnier, with a patent from the French Government, sought to use his machine to manufacture army uniforms. However, 200 tailors rioted, fearing they would be put out of business by the machine. An improved version of Thimonnier's machine was created by Elias Howe, an American inventor, in 1846.

Combined with the industrial textile business in England, this marked the beginning of mass clothing production. It also sparked issues that still plague the fashion industry today. The sewing machine brought with it sweatshops and dire working conditions, still present in Asia, Central and South America. Meanwhile, the ever-increasing speed of changing fashions means large amounts of clothing and fabric end up in landfill. While the Industrial Revolution brought about mighty manufacturing progress, there is still plenty of work to do in terms of its social and ecological legacy.

> **"MUSLIN, PREVIOUSLY RESERVED FOR THE CLOTHES OF THE UPPER CLASSES, BECAME AVAILABLE TO ALL BY 1815"**



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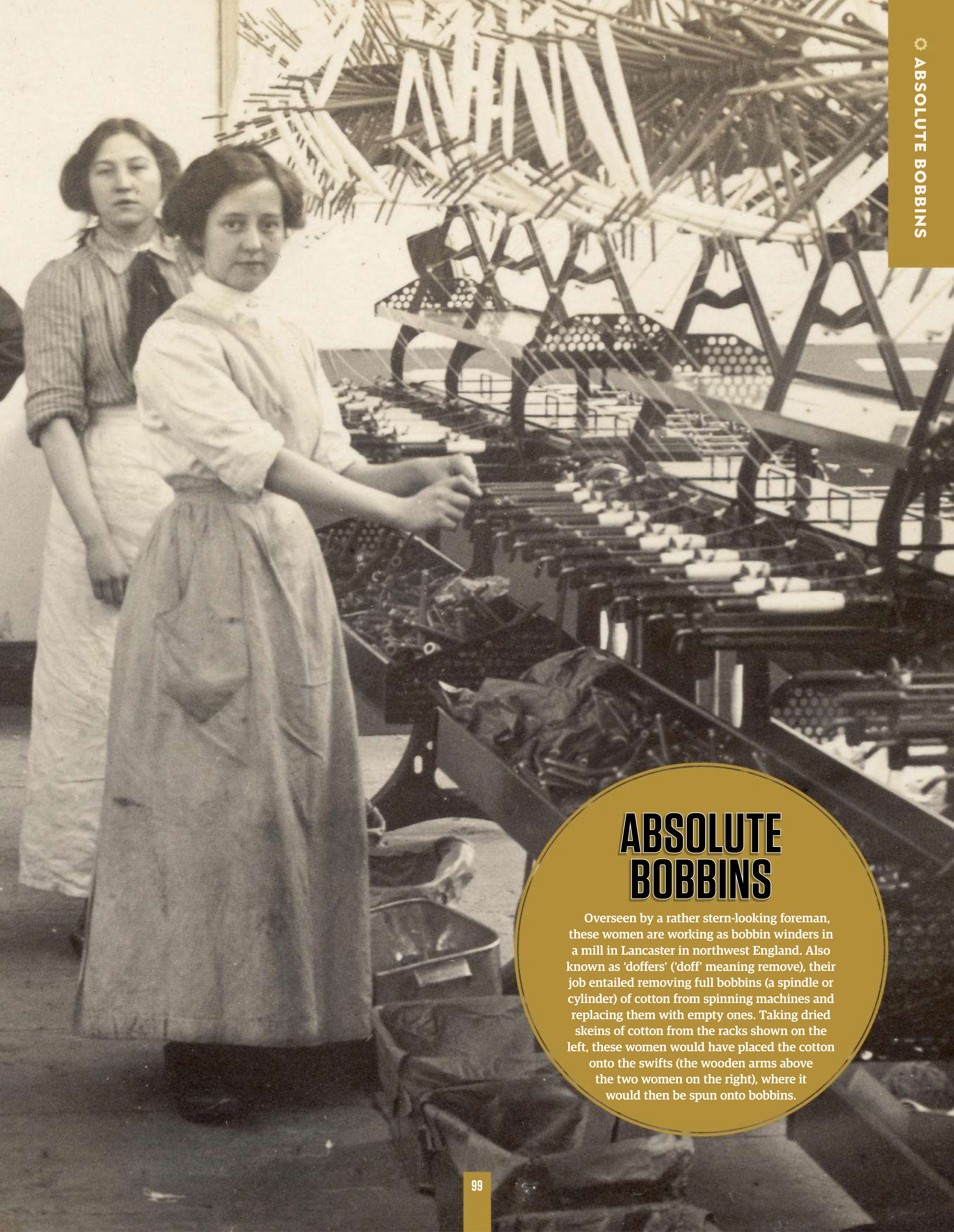


ABSOLUTE BOBBINS

Overseen by a rather stern-looking foreman, these women are working as bobbin winders in a mill in Lancaster in northwest England. Also known as 'doffers' ('doff' meaning remove), their job entailed removing full bobbins (a spindle or cylinder) of cotton from spinning machines and replacing them with empty ones. Taking dried skeins of cotton from the racks shown on the left, these women would have placed the cotton onto the swifts (the wooden arms above the two women on the right), where it would then be spun onto bobbins.

FEED THE MACHINE

Mechanisation didn't just change the way humans worked and travelled – it completely revolutionised how they ate, a transformation in diet that lives on today

Written by Bee Ginger

The early 19th century marked a time of rapid industrialisation in Britain and, courtesy of improved railway links, a noticeable change in the supply, processing, transportation and refrigeration of food.

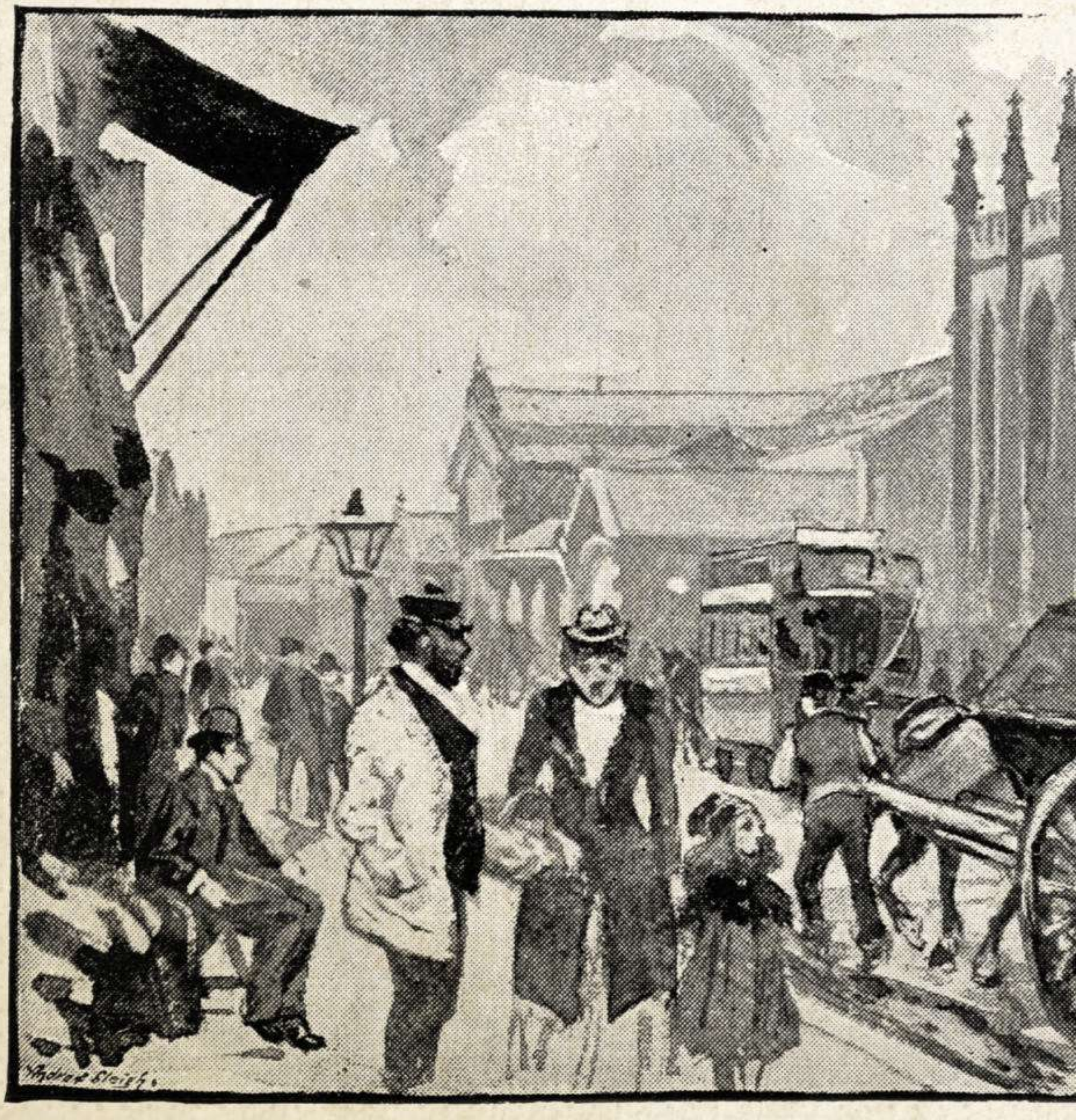
Before the rise of mechanisation, agriculture had been solely reliant on labourers to produce and harvest food. But the Industrial Revolution witnessed unprecedented changes to the nature of farming as machinery made the entire process far more efficient, in turn reducing the demand for labour in rural areas. As factories and mills began to sprout up, demand for workers in urban areas skyrocketed, which naturally encouraged people to seek more secure, lucrative employment in Britain's growing towns and cities. Yet while a new life in places like London and Manchester presented many with the prospect of a more stable existence than that offered by the shifting rural landscape, it also came with its own set of challenges.

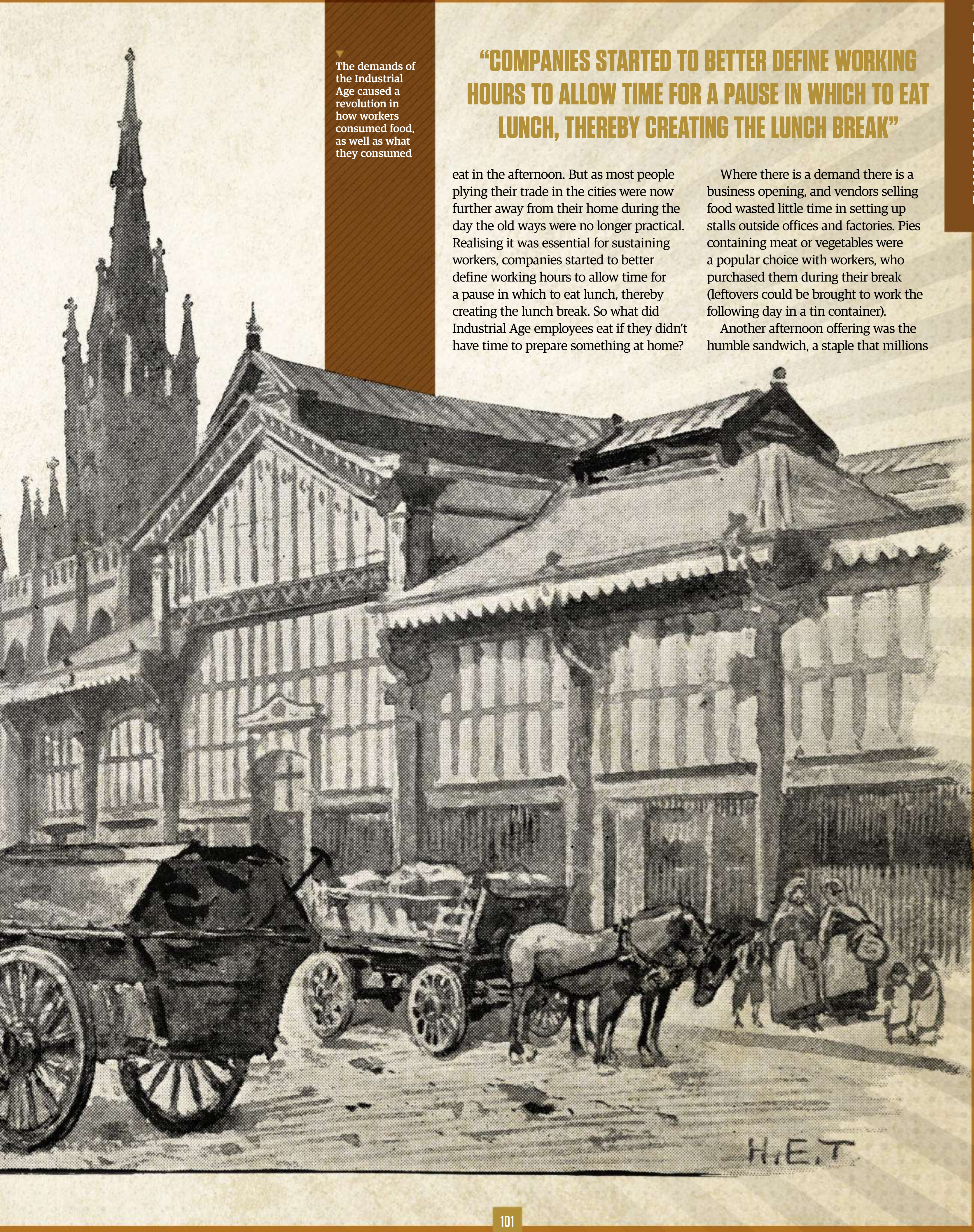
Lack of space in the burgeoning urban areas meant there was no room for families to grow their own produce or keep livestock. This led to society becoming heavily reliant on mass-produced food, and it was Britain that became the first country in the world to feed its people with industrialised food. Many houses were also ill-equipped for food storage and had limited cooking facilities, and workers had little time or energy at the end of a long working day to bother with sophisticated cooking. This led to a boom in the purchasing of pies, sausages and other prepared foods, marking the dawn of something akin to a 19th-century takeaway.

As the population grew, workers found themselves travelling further from home to their place of work, therefore they would require a meal before leaving home in the morning. Because much of their time would involve sitting in one place, a heavy meal before work was not ideal and would result in indigestion, so many opted for a lighter offering. With baked beans not being invented until 1886, cereals became a ubiquitous breakfast option, and there was one brand in particular that would go on to become a fixture on tables across the globe.

John Harvey Kellogg is a name recognised by many as the founder of Kellogg's cereals, which interestingly originated in sanatoriums. A follower of the newly formed Seventh-day Adventist religion, in 1894 Kellogg and his brother were working together on making healthier loaves of bread and quite accidentally created thin flakes out of the wheat dough instead.

Lunch was also shaped by the Industrial Revolution. Prior to the emergence of factories, workers toiling on the land would have returned home to





The demands of the Industrial Age caused a revolution in how workers consumed food, as well as what they consumed

> "COMPANIES STARTED TO BETTER DEFINE WORKING HOURS TO ALLOW TIME FOR A PAUSE IN WHICH TO EAT LUNCH, THEREBY CREATING THE LUNCH BREAK"

eat in the afternoon. But as most people plying their trade in the cities were now further away from their home during the day the old ways were no longer practical. Realising it was essential for sustaining workers, companies started to better define working hours to allow time for a pause in which to eat lunch, thereby creating the lunch break. So what did Industrial Age employees eat if they didn't have time to prepare something at home?

Where there is a demand there is a business opening, and vendors selling food wasted little time in setting up stalls outside offices and factories. Pies containing meat or vegetables were a popular choice with workers, who purchased them during their break (leftovers could be brought to work the following day in a tin container).

Another afternoon offering was the humble sandwich, a staple that millions of people across the world still eat today. John Montagu, 4th Earl of Sandwich, is credited with inadvertently inventing it when he ordered his butler to bring him some cold meats between some slices of bread to avoid getting grease on his work.

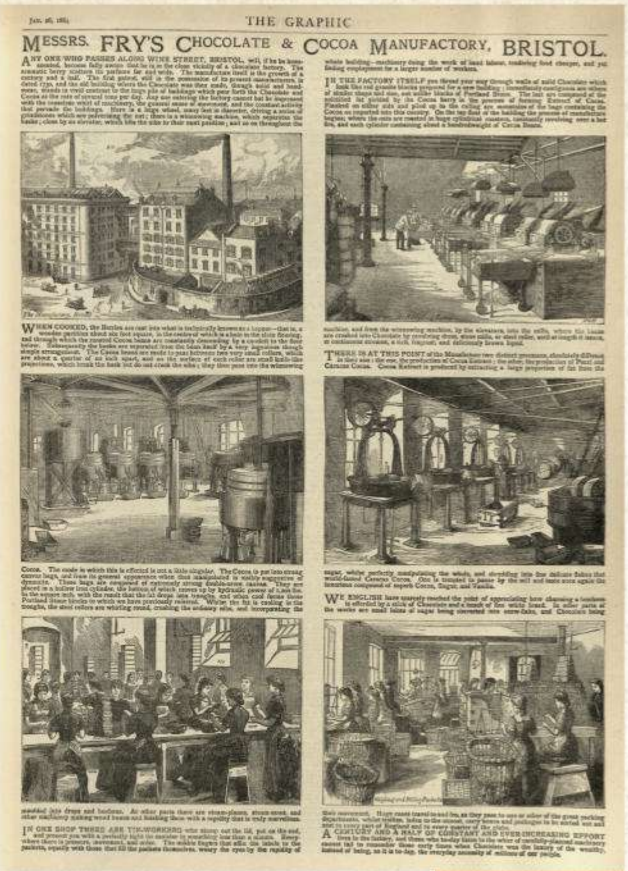
Eager to keep their work force alert and productive, industrial tycoons encouraged coffee breaks. Where beer had once been the beverage of choice as it provided calories and a hydration of sorts and, unlike a lot of water, wasn't polluted, coffee, tea and cocoa gradually replaced it as people's daily habits changed. Fry's launched British Workman's Cocoa in 1874 as attitudes towards alcohol shifted due to the understanding that a person needed to be sober in order to be able to operate heavy machinery safely. Halls serving hot drinks opened across the country and cocoa makers made the most of advertising the benefits of cocoa as an alternative to alcohol. In their London factory, Frederick Allen & Sons made a host of chocolate products including chocolate powder, homoeopathic cocoa and pearl cocoa, all of them aimed at the breakfast market.

"ATTITUDES TOWARDS ALCOHOL SHIFTED... A PERSON NEEDED TO BE SOBER TO OPERATE HEAVY MACHINERY SAFELY"

Although the world around them was constantly changing as machines broke new ground, an average worker's diet remained relatively simple and was largely dictated by what they could afford and also the availability of certain foods. This often fluctuated due to poor harvests (the result of which was a shortage of some foods and higher prices). Hearty meals often consisted of cheaper cuts of meat like bacon, which would be cooked with a watery, cabbage-like soup.

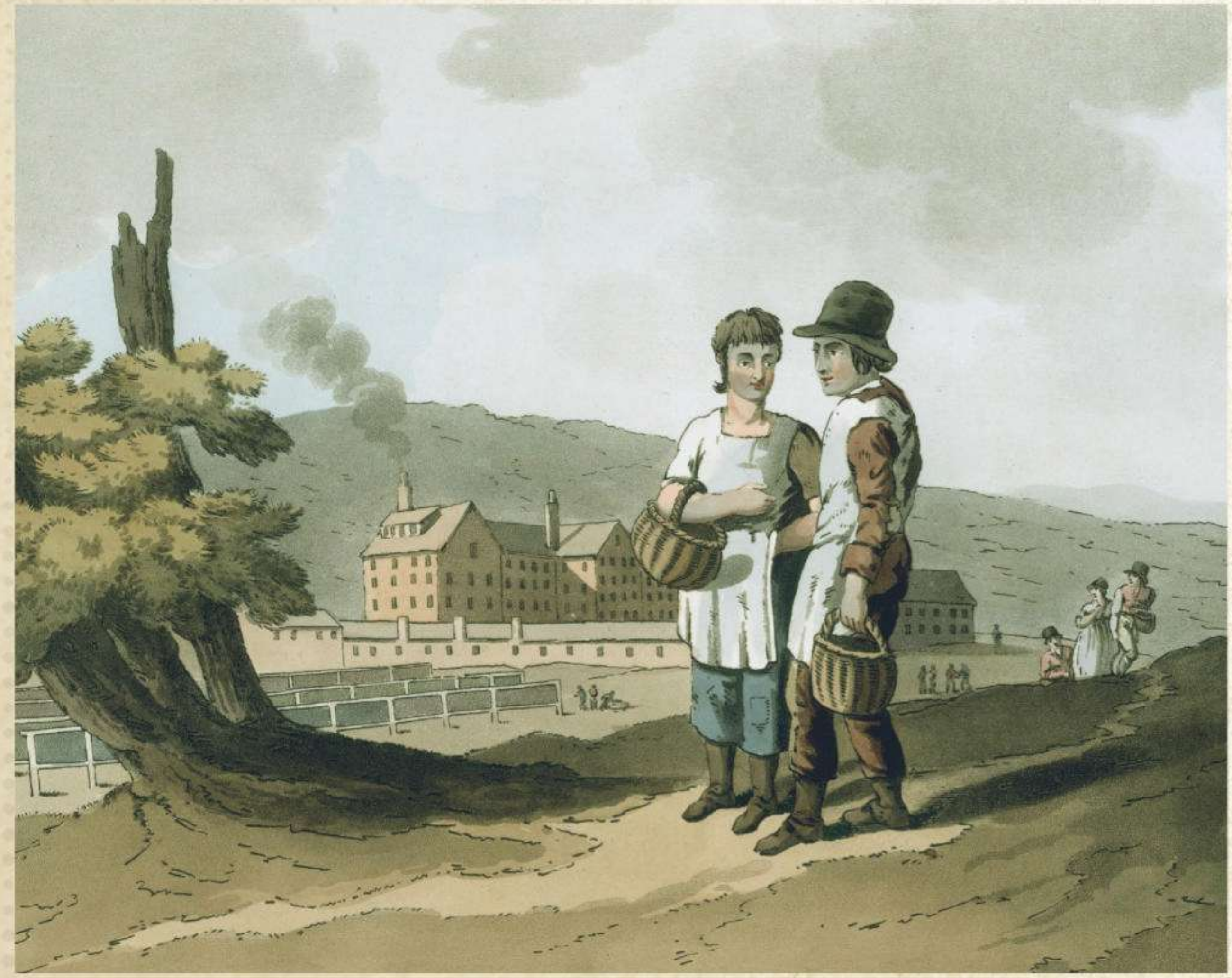
A slithery alternative was eel, especially in the London area, where they swam in the River Thames. Even when the water became polluted by nearby factories, the poorer inhabitants of the East End dined on jellied eel. It remains a traditional meal today, best served with pie and mash.

The poor were afforded slim pickings when it came to their evening meal and subsisted on a meagre diet of bread and



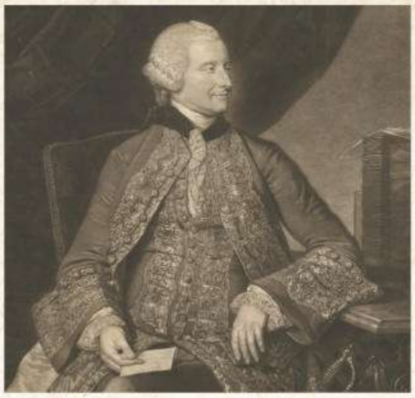
THE GRAPHIC

MESSRS. FRY'S CHOCOLATE & COCOA MANUFACTORY, BRISTOL.



▲ Fry's chocolate factory, which originated in Bristol, was the first chocolate producer to create a solid chocolate bar, filled chocolates and cream sticks. You can still buy Fry's Turkish Delight today

◀ This illustration by George Walker, titled *The Costume of Yorkshire*, shows factory workers carrying their day's food in baskets. The background depicts a typical West Riding cotton mill, with sheets of material hanging outside to dry on tenterhooks



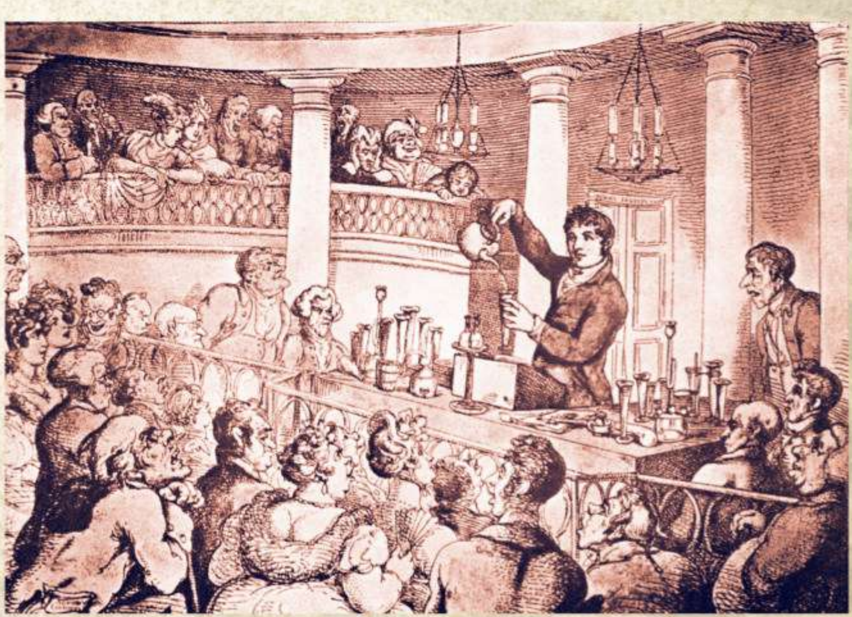
Said to have been invented in the 1700s by Lord Sandwich (left), the humble sandwich still dominates most lunch menus

potatoes washed down with a weak tea. Treats such as cheese, butter or offal were a rarity. Tea leaves were reused numerous times, and with food quality regulations still in their infancy, meats like pork, lamb and beef were often sold from diseased animals, which could cause food poisoning. Food adulteration was also common among the poor (food mixed together with other products in order to bulk it out). Adding chalk and water to milk in order to make it stretch further was one of countless examples.

The food-processing industry continued to go from strength to strength, as did the study and addition of flavours, emulsifiers, colours and thickeners, all liberally added to food. Dairy products like butter and cheese were coloured with copper or lead, and sweets were given a dash of copper arsenite to improve their colour. It is copper arsenite that was also used in wallpaper and rumoured to have possibly played a part in the death of Napoleon.

Canned foods became all the rage as the development of canning technology made it possible to preserve foods for longer periods. Similarly, pickling produce and making preserves like jam became an option for those without refrigeration. Potatoes, too, could be purchased in small quantities and easily stored. However, nothing came close to bread in terms of its consumption, which was fuelled by the introduction of steam-powered mills. Miners were reported to have spent around 25 per cent of their earnings on bread, factory workers an impressive 36 per cent. Baked goods also became popular in all areas of society, with the more affluent partaking in afternoon teas with crumpets and cake. And while sugar was expensive, puddings slowly crept onto dinner tables across the land. Pastries, cakes, sweet fruit pies and biscuits became more readily available and heralded the birth of the much-loved Garibaldi biscuit, which was one of the first prepackaged and commercially produced foods of the time. The tone was set for mass production and the use of packaged products.

Miners and pottery workers ate oatcakes, which were cheap and easy to make on coal-fired bakestones



German chemist Friedrich Accum gives a lecture on food adulteration at the Surrey Institution, London

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VICTORIA'S EMPIRE

How a tiny island in the Atlantic Ocean came to own an empire so large that the Sun never set on it

Written by Frances White

The date was 22 January 1901, and the British Empire was the largest of any in human history, but the monarch who reigned over it would not live another day. As Queen Victoria lay dying in Osborne House on the Isle of Wight she looked back on a reign that spanned over 63 years. She had seen her empire grow from a collection of scattered isles separated by vast plains of lands and insurmountable oceans to the greatest the world had known. It had reached over India, plucked its riches and mounted it as the glimmering jewel in her crown. It had butchered its way mercilessly across Africa at the cost of thousands of British corpses and countless natives who had tried in vain to stand in its way. It was powered forward both by Christian values and colonial greed, so as Victoria drew her last breath she left a world forever transformed by the empire she had built.

When a young Princess Victoria ascended the steps of Westminster Abbey on her coronation day, few would have foreseen the mighty empire she would eventually rule over. The British public were increasingly disenchanted with the monarchy, and her grandfather, the mad king George III, had failed to protect British interest in the Americas, while her uncle George IV's terrible relations with his wife and reckless spending had tarnished the monarchy's prestige. At a mere 18 years and barely 150 centimetres (five feet) tall, Victoria hardly seemed a fitting patron for the vast ambitions of British expansion from the 17th century. But this blue-eyed, silvery-voiced lady possessed a stubborn will of iron, and her reign would become the second-longest in British history. Her ascension marked not the death of the British Empire but the new dawn of a kingdom so massive that none could ever hope to challenge it.

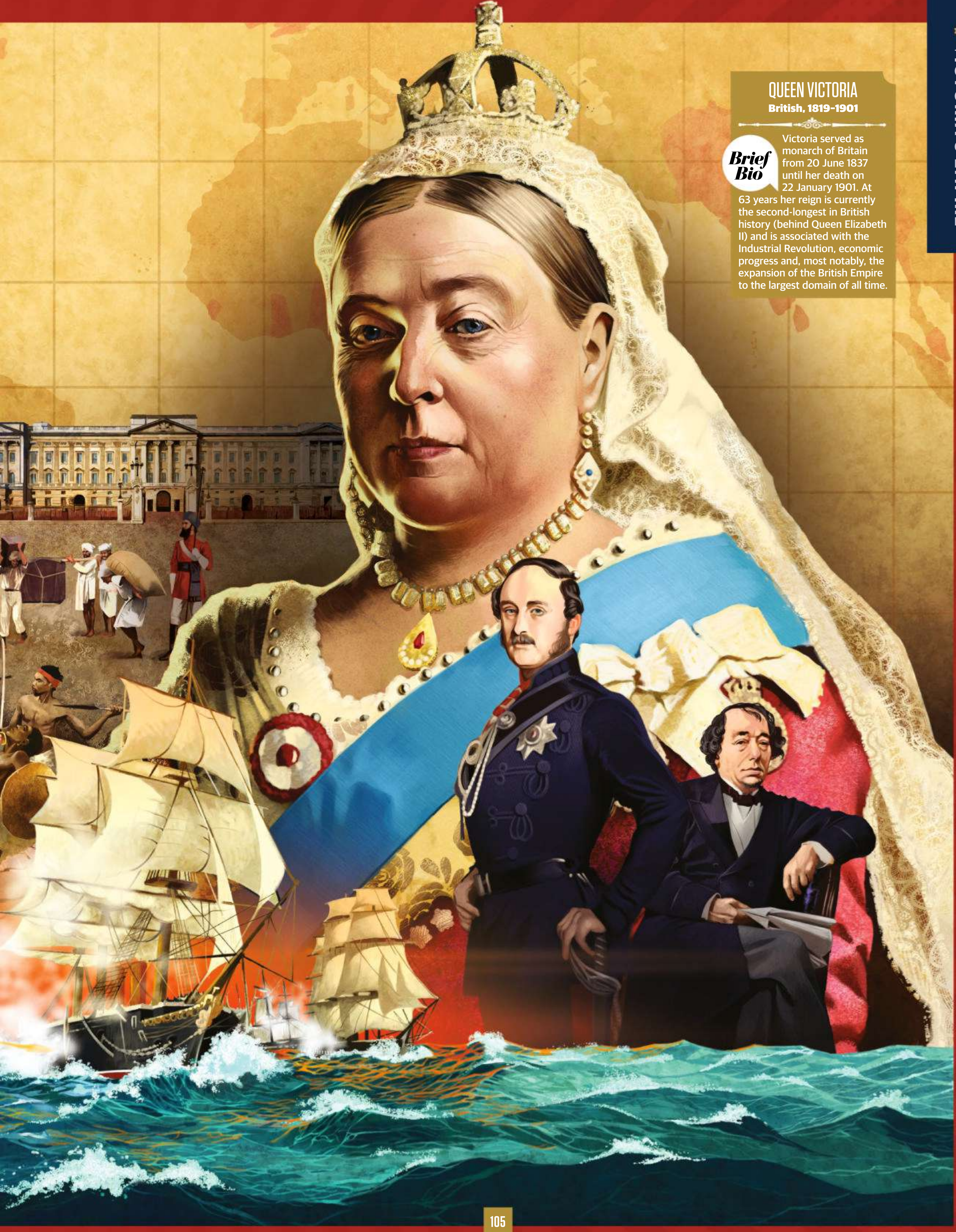
The world was changing as Victoria took her place on the throne. The tiny, scattered rural villages of England were being abandoned en masse and the cities were transforming into sprawling metropolises. Great towering concrete chimneys rose from the ground and the whirr of machines sounded across the country – the age of steam had arrived.

The Industrial Revolution changed Britain from a quaint maritime nation into a manufacturing colossus. Railways and steamships brought the British overseas territories closer to the mother country that ruled over them, opening up opportunities for trade and commerce that were previously unfathomable.

"THE BRITISH EMPIRE HAD THE MIGHT, INGENUITY AND LIMITLESS AMBITION TO CONQUER THE WORLD"

It was Albert, Victoria's beloved husband, who opened her and Britain's eyes to the ideas that went on to shape her empire. Fascinated by mechanisms and inventions, Albert organised The Great Exhibition at the Crystal Palace – a temple to the ingenuity of the rapidly developing modern world. Inventions from around the world were displayed, but this was Britain's show first and foremost. The symbols of British might, which occupied half of the entire display space, served as clear examples of what the British Empire was capable of and fostered the ideas of national supremacy in the eyes of Victoria, the government and the majority of the British population. The Great Exhibition proved that far from the crumbling remains of a once-powerful nation, the British Empire had the might, ingenuity and limitless ambition to conquer the world.

The opportunity to pave the road for this empire arose in 1857 with the Indian Mutiny. India had been ruled by a private



QUEEN VICTORIA

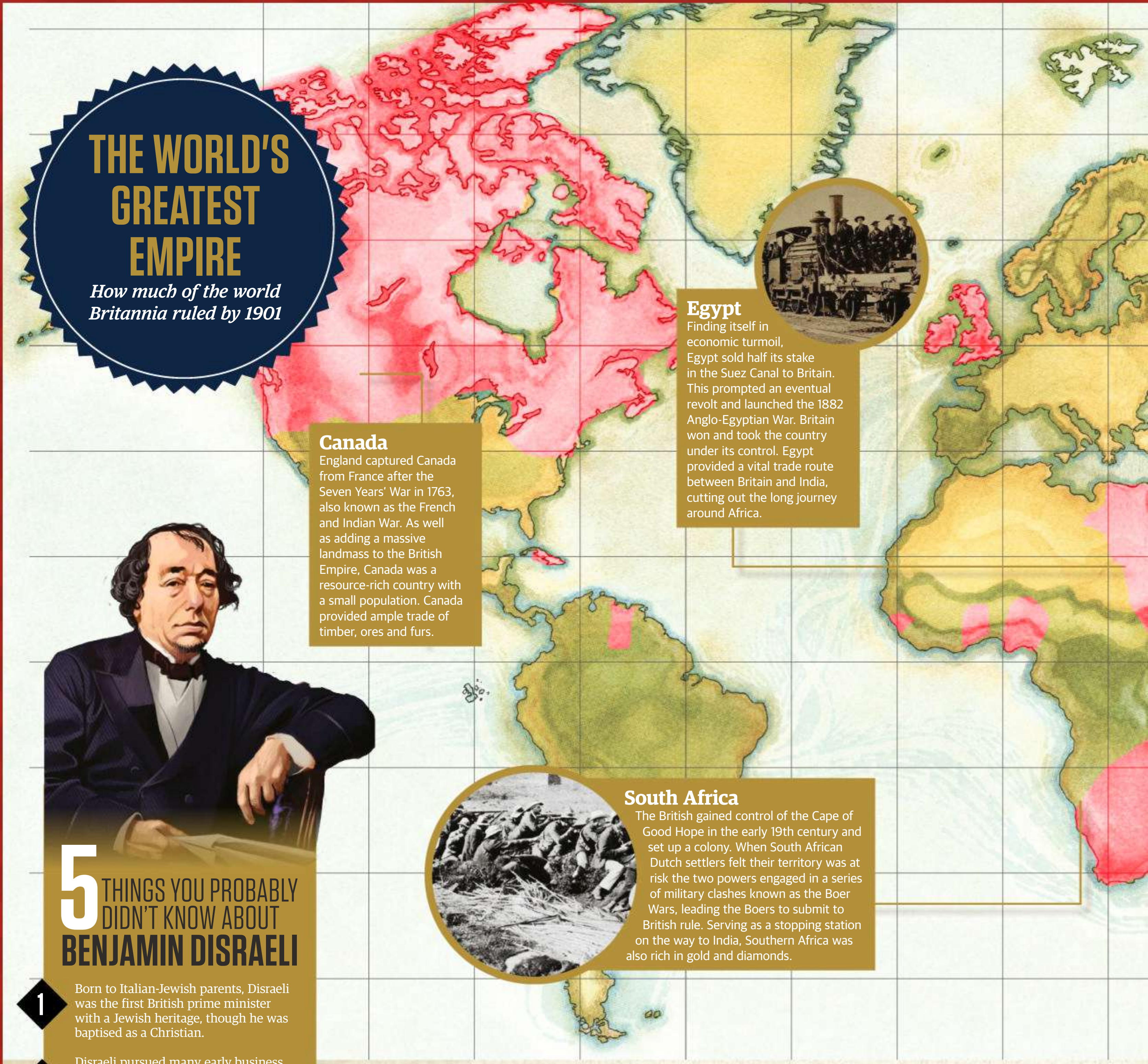
British, 1819-1901

Brief Bio

Victoria served as monarch of Britain from 20 June 1837 until her death on 22 January 1901. At 63 years her reign is currently the second-longest in British history (behind Queen Elizabeth II) and is associated with the Industrial Revolution, economic progress and, most notably, the expansion of the British Empire to the largest domain of all time.

THE WORLD'S GREATEST EMPIRE

How much of the world Britannia ruled by 1901



Canada
England captured Canada from France after the Seven Years' War in 1763, also known as the French and Indian War. As well as adding a massive landmass to the British Empire, Canada was a resource-rich country with a small population. Canada provided ample trade of timber, ores and furs.

Egypt
Finding itself in economic turmoil, Egypt sold half its stake in the Suez Canal to Britain. This prompted an eventual revolt and launched the 1882 Anglo-Egyptian War. Britain won and took the country under its control. Egypt provided a vital trade route between Britain and India, cutting out the long journey around Africa.

South Africa
The British gained control of the Cape of Good Hope in the early 19th century and set up a colony. When South African Dutch settlers felt their territory was at risk the two powers engaged in a series of military clashes known as the Boer Wars, leading the Boers to submit to British rule. Serving as a stopping station on the way to India, Southern Africa was also rich in gold and diamonds.

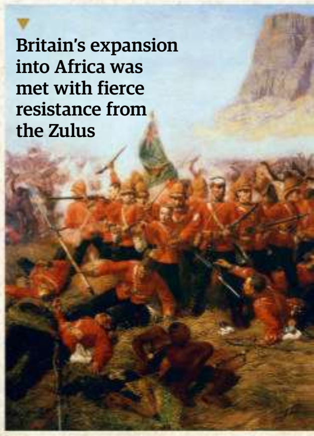
5 THINGS YOU PROBABLY DIDN'T KNOW ABOUT BENJAMIN DISRAELI

1. Born to Italian-Jewish parents, Disraeli was the first British prime minister with a Jewish heritage, though he was baptised as a Christian.
2. Disraeli pursued many early business ventures that failed, leaving him in crippling debt and leading to a nervous breakdown from which it took him years to recover.
3. He was mocked in Parliament when he made his maiden speech. Later he proclaimed that "the time will come when you will hear me."
4. Disraeli was a notorious flatterer and when asked by a colleague how to deal with Queen Victoria, he replied, "First of all, remember she is a woman."
5. He introduced much legislation that benefited the poor, such as the 1877 Artisans Dwelling Act that provided housing, as well as the Public Health Act the same year.

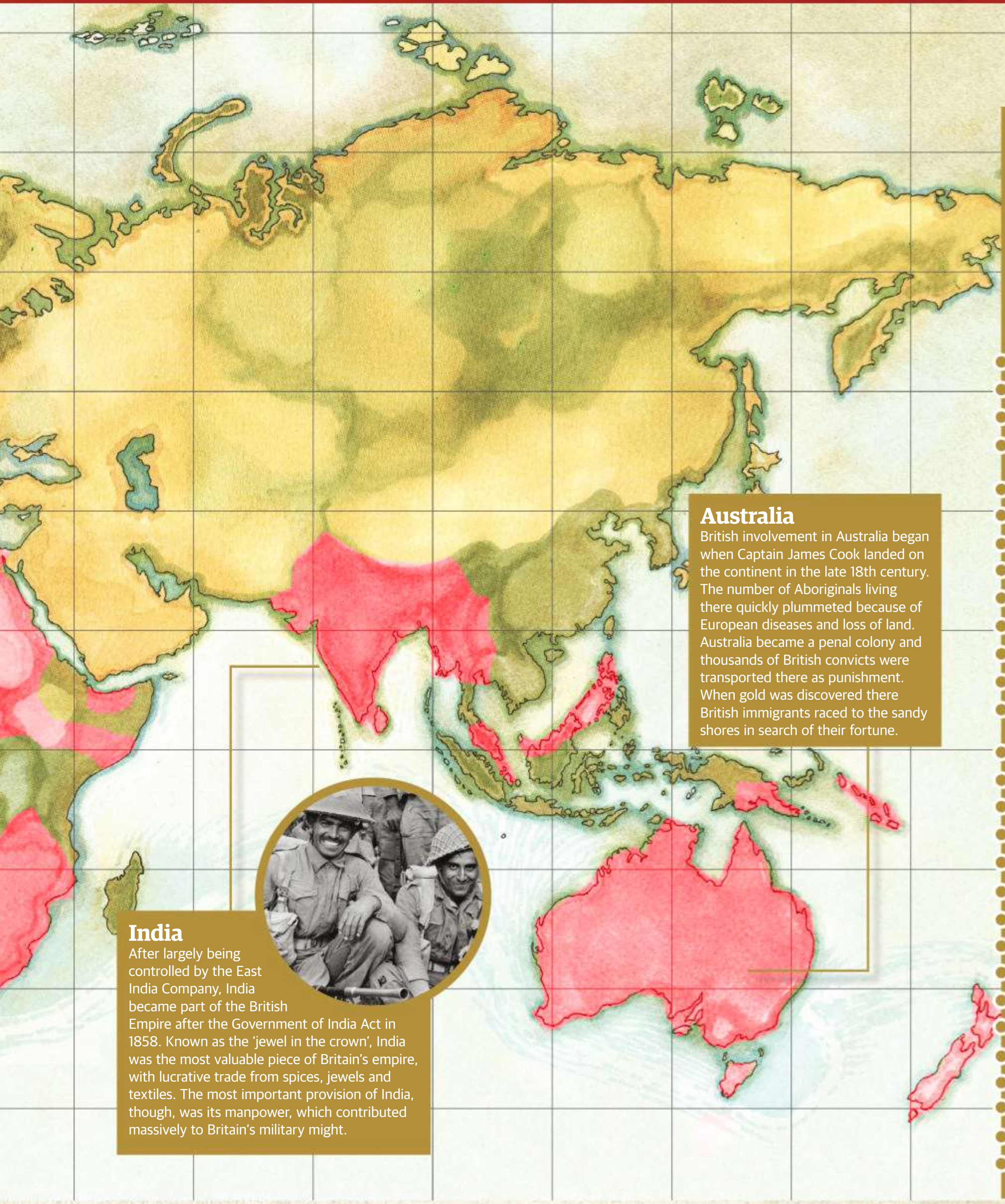
> “THE LOSS OF THE LOVE OF HER LIFE CHANGED NOT ONLY HERSELF AS A PERSON BUT THE FATE OF HER EMPIRE”

entity – the East India Company (EIC) – from 1757. The rebellion manifested the discontent felt by the Indian people for the blatant disrespect of their beliefs and customs shown by the EIC. The company showed disregard for the Indian caste system and issued new cartridges greased with cow and pig fat that had to be opened with the mouth, highly offensive to Muslim and Hindu soldiers. These actions opened the eyes of the Indian people to the daily injustice they were being subjected to, and unrest snowballed into mass riots and an uprising. Although the mutiny was eventually quelled, the rebellion led to the dissolution of the company, the passing of power to the British state and the creation of what Victoria would call the jewel in her crown – the British Indian Empire.

Queen Victoria welcomed the country to her empire in a lavish ceremony,



▼ Britain's expansion into Africa was met with fierce resistance from the Zulus



India

After largely being controlled by the East India Company, India became part of the British Empire after the Government of India Act in 1858. Known as the 'jewel in the crown', India was the most valuable piece of Britain's empire, with lucrative trade from spices, jewels and textiles. The most important provision of India, though, was its manpower, which contributed massively to Britain's military might.

Australia

British involvement in Australia began when Captain James Cook landed on the continent in the late 18th century. The number of Aboriginals living there quickly plummeted because of European diseases and loss of land. Australia became a penal colony and thousands of British convicts were transported there as punishment. When gold was discovered there British immigrants raced to the sandy shores in search of their fortune.

TIMELINE OF CONQUEST

How Victoria's British Empire became the world's biggest

- 1838 PICAIRN ISLANDS
- 1842 HONG KONG
- 1848 INDIA
- 1853 TRUCIAL OMAN (TRINIDAD & TOBAGO)
- 1857 ADEN (YEMEN)
- 1862 BRITISH HONDURAS (BELIZE)
- 1868 BECHUANALAND (BOTSWANA)
- 1874 FIJI
- 1878 CYPRUS
- 1878 SOUTH WEST AFRICA (NAMIBIA)
- 1881 NORTH BORNEO (SABAH)
- 1884 BASUTOLAND (LESOTHO)
- 1884 BRITISH SOMALILAND (SOMALILAND)
- 1884 PAPUA NEW GUINEA
- 1885 NIGERIA
- 1885 KENYA
- 1887 MALDIVE ISLANDS
- 1888 BRITISH EAST AFRICA (KENYA)
- 1888 BRUNEI
- 1888 COOK ISLANDS (NZ ASSOC.)
- 1888 GAMBIA
- 1888 SARAWAK (MALAYSIA)
- 1889 RHODESIA (ZIMBABWE)
- 1889 TRINIDAD (TRINIDAD & TOBAGO)
- 1890 TANGANYIKA (TANZANIA)
- 1891 MALAWI
- 1894 UGANDA
- 1898 SUDAN
- 1899 KUWAIT

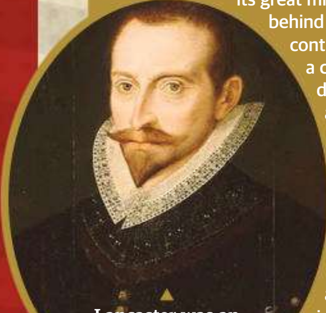
promising that Indian native customs and religions would be respected and that she would "draw a veil over the sad and bloody past". She presented herself as a maternal figure and a crusader for peace, justice and honest government - ideals largely inspired by her husband. Albert had instilled in her mind the vision of King Arthur's Camelot, an empire ruled not by tyranny but by justice, where the strong serve the weak, where good triumphs over evil, bringing not oppression and bloodshed but trade, education and welfare. His influence on Victoria was immense, and when on 14 December 1861 he died of suspected typhoid fever, the empire veered into an entirely new direction.

When Albert drew his last breath in the blue room at Windsor Castle the queen was inconsolable; the loss of the love of her life changed not only herself as a person, but the fate of her empire. As she donned the mourning clothes she would wear until her own death she drew a veil over Albert's vision and pursued a different path for her kingdom - one of world domination.

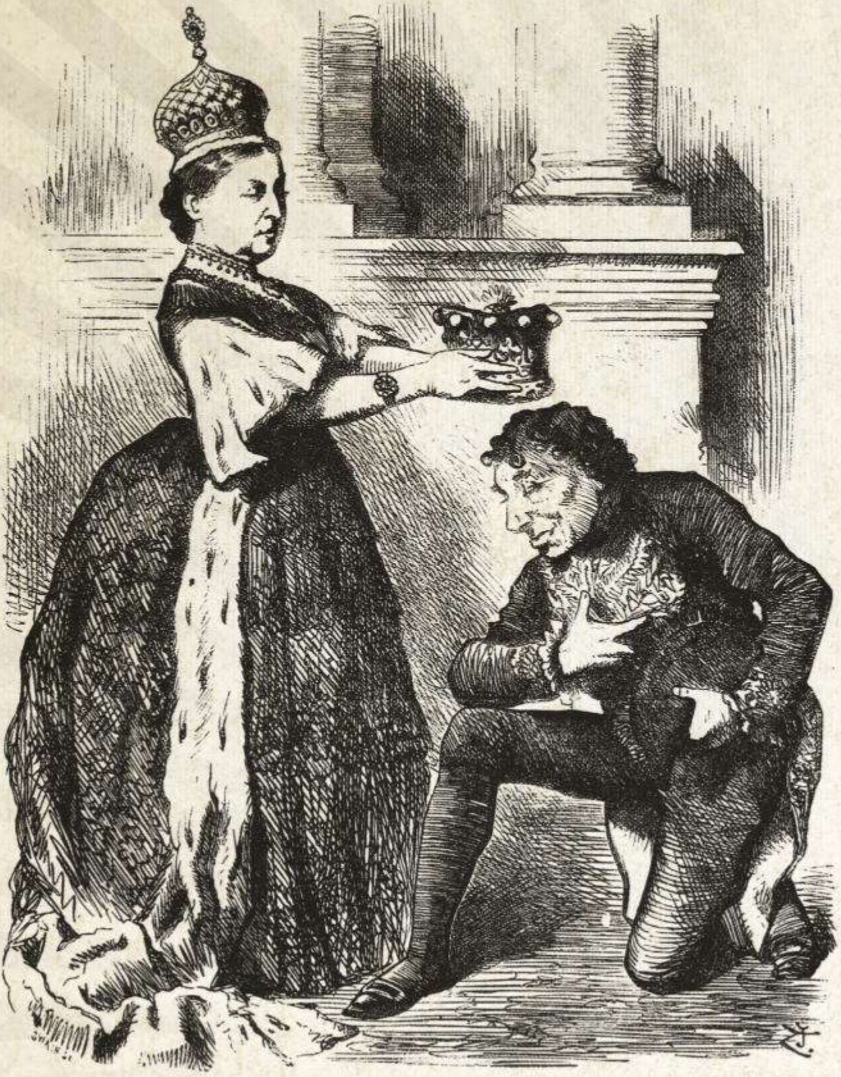
An emerging figure in Parliament would come to foster her views in the form of Benjamin Disraeli. The ambitious and rebellious leader of the Conservatives was fuelled by a passion for imperial power and glory. Inspired by tales of imperial adventures, Disraeli believed Britain should pursue an empire of power and prestige. His most direct political opponent represented everything Albert dreamed the empire could be. William Gladstone, the leader of the Liberals, thought the empire should serve a high moral purpose, to follow not a path of conquest but one of commerce and sharing their moral vision with the rest of the world.

WHAT WAS THE EAST INDIA COMPANY?

Emerging from humble beginnings, the East India Company began as a simple enterprise of London businessmen who wanted to make money from importing spices. The company was granted a royal charter by Queen Elizabeth I in 1600, and in 1601 James Lancaster led its first voyage. The company set up trade outposts in Indian settlements that slowly developed into commercial towns. Steadily increasing its territory, the company claimed vital trading ports from Aden to Penang. As its control extended the company became the most powerful private company in history, with its own army established by Robert Clive, the first British governor of Bengal. With its great military power behind it, the company controlled India with a combination of direct rule and alliances with Indian princes. The East India Company eventually accounted for half the world's trade and specialised in cotton, silk, tea and opium.



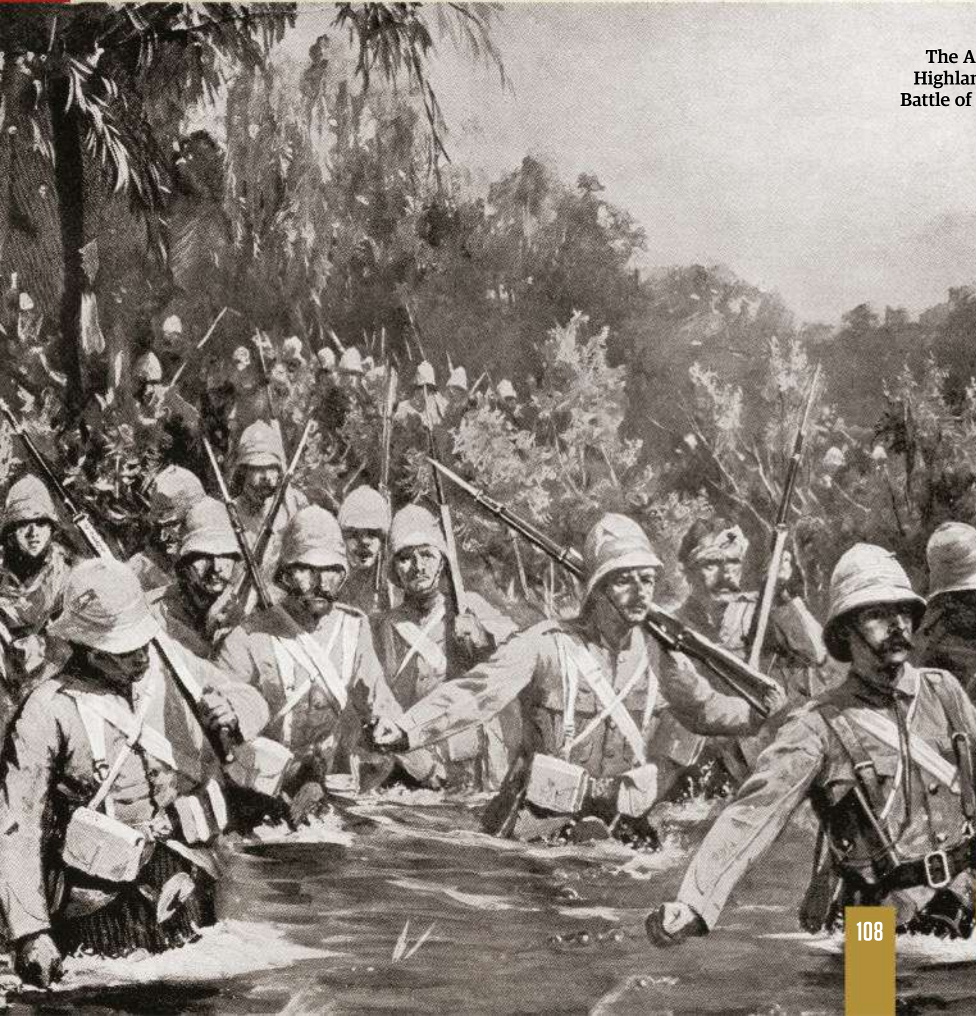
Lancaster was an Elizabethan trader and privateer



A satirical cartoon from 1876 poking fun at the relationship between Queen Victoria and Benjamin Disraeli

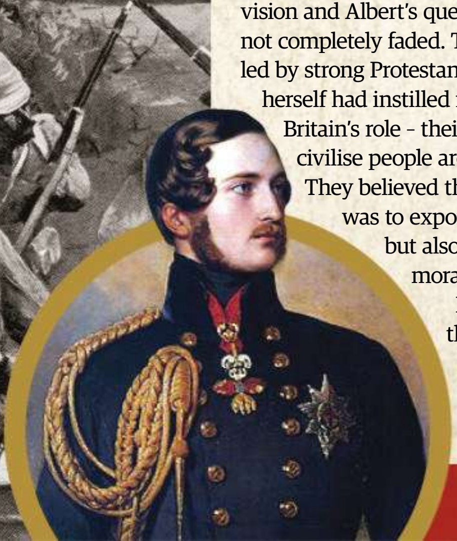
A British marketing poster promoting the Suez Canal. The waterway was an important factor in the growth of the empire

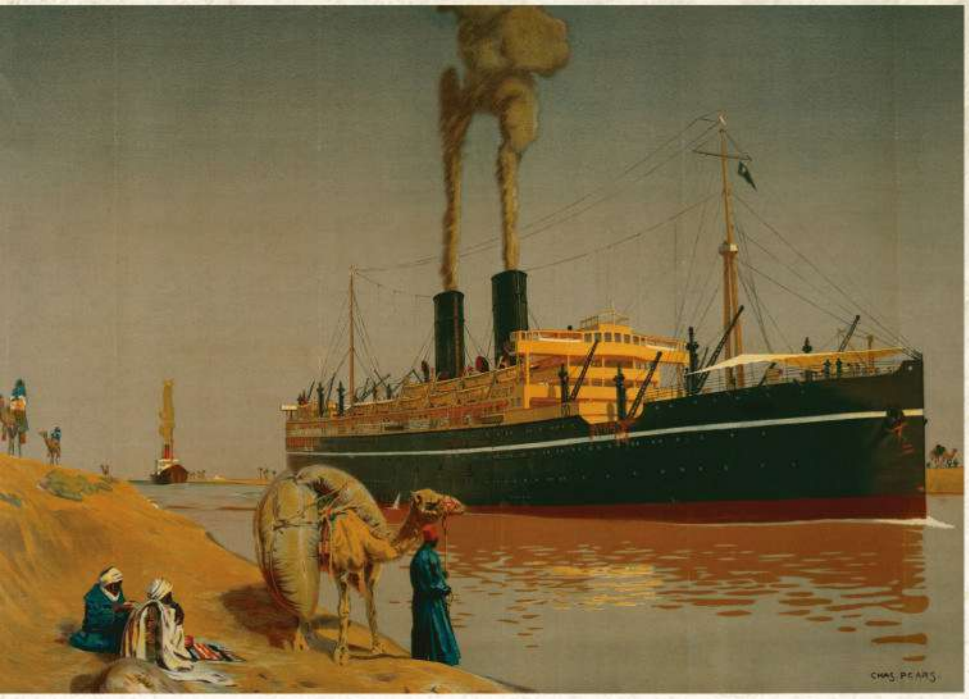
Prince Albert was only 42 when he died at Windsor Castle in December 1861



The Argyle and Sutherland Highlanders before the 1899 Battle of Modder River during the Second Boer War

These two fiery and driven men fought over these opposing visions in Parliament as Victoria continued to mourn. Without Albert she felt incompetent and unable to face the immense duty that her role dictated. With her strong conservative views she found Gladstone and his liberal reforms dangerous and unpredictable. Disraeli, suave, coy and dripping with forthright confidence, enchanted the lonely queen. With his constant flattery and sharp wit, Disraeli reignited her interest in politics and captivated her, as Albert had done so previously, with his vision of just how mighty the empire could be. However, Gladstone's liberal vision and Albert's quest for Camelot had not completely faded. The British people, led by strong Protestant beliefs Victoria herself had instilled in them, felt it was Britain's role - their duty even - to civilise people around the world. They believed the British cause was to export not only trade but also gospel values of morality and justice. It was in pursuit of this lofty goal that many missionaries





> "THE INDUSTRIAL REVOLUTION CHANGED BRITAIN FROM A QUAINT MARITIME NATION INTO A MANUFACTURING COLOSSUS"

turned their attention to Africa. Little was known of the 'Dark Continent', but the common perception was that it was a place of pagan worship ravaged by tribal wars. One missionary in particular would capture the attention of the British nation.

Tall, handsome and heroic, David Livingstone embodied everything the British believed their nation to represent. A medical missionary, Livingstone's daring adventures around the continent were followed by a captivated British public. Fighting vicious beasts, battling through dense jungles and suffering a multitude of illnesses, Livingstone was the heroic face of the empire's Christian ideals.

Livingstone's horrific confrontation with African chain gangs was to drive the British cause of expansion. The slavery rife in Africa was abhorrent to Livingstone and the British public, as the practice had been abolished across the empire in 1833. The queen and government united behind Livingstone's quest to find a suitable trade route, hoping that by doing so the African people would find ways to make a living that wasn't built on the backs of slaves.

Unfortunately for Livingstone, his journey was a failure and he returned to scathing criticism – something the imperialist Disraeli leapt on with glee. His flattery of Victoria had completely won her over, and the monarchy and government became united in pursuit of one goal – the expansion of the empire.

The perfect opportunity to begin this new empire emerged as another nation struggled to survive. The Egyptian ruler, Isma'il Pasha, was confronted with crippling debts after reckless spending on lavish ceremonies and a costly war with Ethiopia. In an act of desperation he made an offer to sell to the British Egypt's shares in the Suez Canal. The canal was more than a mere trading port; it opened up a short route to India across Egypt and down the Red Sea, cutting out the lengthy journey around Africa. The Egyptian ruler's offer would give the British controlling influence over much of the world's trade, so Disraeli urged Victoria to accept. She immediately did and the Suez Canal passed into British hands.

With control of India, Britain was already the most powerful nation on Earth, and three-quarters of the world's trade was transported in British ships, but this control was being threatened. The Russian Empire had been steadily expanding east and south and was getting uncomfortably close to Victoria's prized jewel: India. The Middle East was largely controlled by the Turks, but they were busy dealing with violent rebellions. The Turkish treatment of their Christian subjects was shocking and atrocious, but as Russia backed the rebels the British had no option but to support the Turks. The British public, to whom Russia stood for everything Britain opposed – ignorance,

FIVE REASONS THE BRITISH EMPIRE CAME TO RULE THE WORLD

DOMINANCE OF THE SEAS

Britain employed a 'two-power standard' in 1889 that called for the Royal Navy to maintain a force at least equal to the combined strength of the next two largest navies in the world. This policy ensured British dominance of the seas with a string of naval bases built across the world. The pure size and strength of the navy served its purpose – deterring any would-be competitors and confirming its position as ruler of the waves.

THE INDUSTRIAL REVOLUTION

Britain was the first nation to harness the power of steam and the first to undergo an industrial revolution. This resulted in mass production of low-cost goods to trade around the world. It also gave Britain's military an array of resources like rifles, steamships and trains, equipping it to defeat any possible enemies. Medical advances also allowed British explorers to penetrate remote areas without fear of tropical diseases.

THE QUEST TO SPREAD DEMOCRACY

Land grabbing aside, the British Empire was led by a strong Protestant desire to improve the world. Britain saw itself as an agent of civilisation, one they wanted to spread worldwide, bringing peace, order and stability. This belief that they were doing genuine good led men such as David Livingstone to travel to Africa to spread the word of God, and with it, the influence of the British Empire.

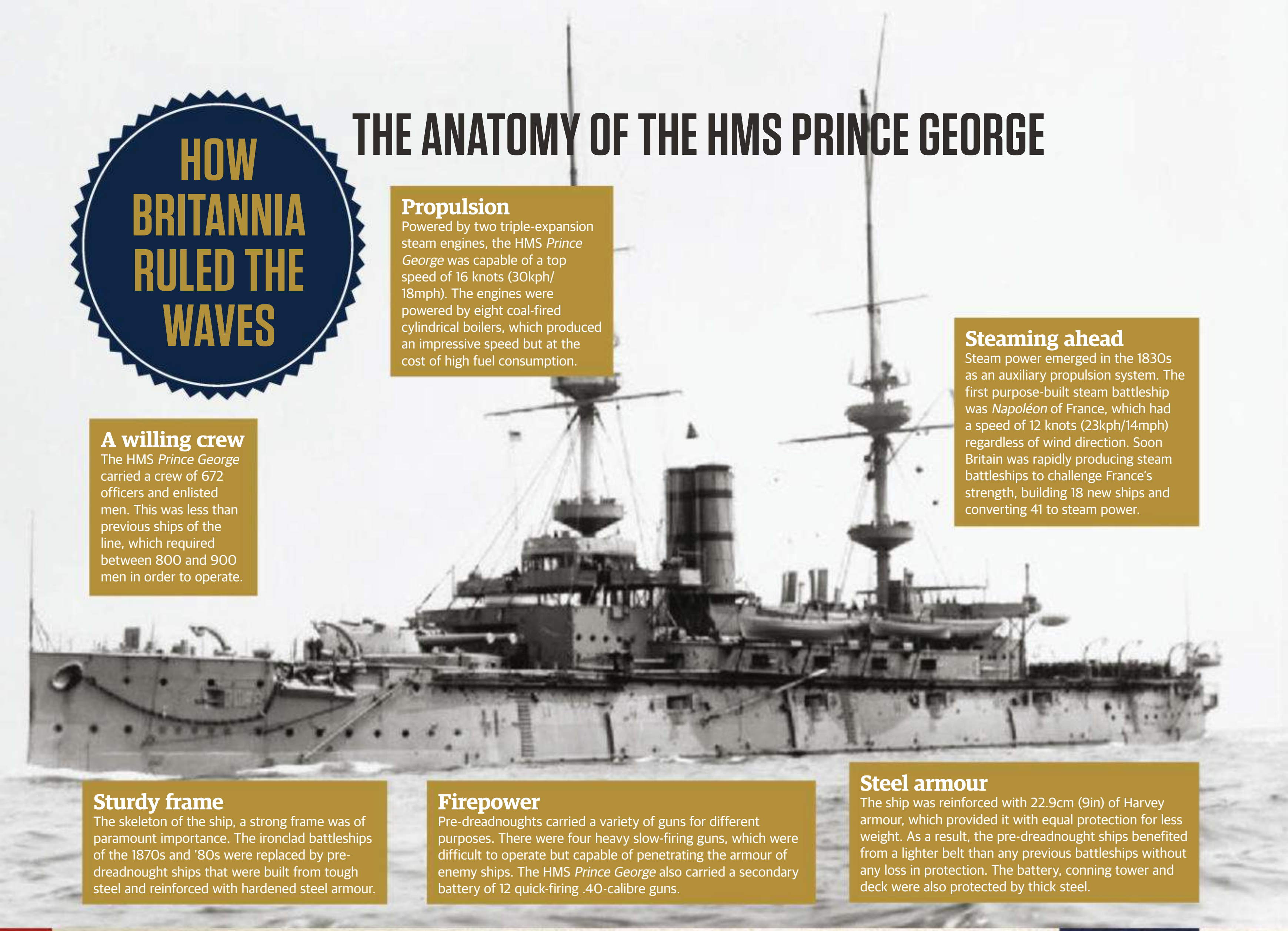
TAKING ADVANTAGE OF THE COMPETITION

As major powers of the world such as Spain, France, the Netherlands and the Ottomans were losing power, the British began to peak in strength. Britain was able to take advantage of the European wars that had weakened other nations as it enjoyed a period of relative peace, allowing uninterrupted expansion of its empire. Any threats that did emerge, such as Russia, just gave Britain new zeal to cement its powerful hold on the world.

STRONG LEADERSHIP

Britain was ruled by a single monarch throughout most of the 19th century – Queen Victoria. The remarkable length of her reign brought a sense of stability and contributed to the unconquerable notion of the British Empire. Although Victoria did involve herself in government, her role was symbolic rather than one of direct power, which ensured stability in British politics. While other nations were dealing with socialist movements, Britain enjoyed a long period of relative domestic peace.

THE ANATOMY OF THE HMS PRINCE GEORGE



Propulsion
Powered by two triple-expansion steam engines, the HMS *Prince George* was capable of a top speed of 16 knots (30kph/18mph). The engines were powered by eight coal-fired cylindrical boilers, which produced an impressive speed but at the cost of high fuel consumption.

Steaming ahead
Steam power emerged in the 1830s as an auxiliary propulsion system. The first purpose-built steam battleship was *Napoléon* of France, which had a speed of 12 knots (23kph/14mph) regardless of wind direction. Soon Britain was rapidly producing steam battleships to challenge France's strength, building 18 new ships and converting 41 to steam power.

A willing crew
The HMS *Prince George* carried a crew of 672 officers and enlisted men. This was less than previous ships of the line, which required between 800 and 900 men in order to operate.

Sturdy frame
The skeleton of the ship, a strong frame was of paramount importance. The ironclad battleships of the 1870s and '80s were replaced by pre-dreadnought ships that were built from tough steel and reinforced with hardened steel armour.

Firepower
Pre-dreadnoughts carried a variety of guns for different purposes. There were four heavy slow-firing guns, which were difficult to operate but capable of penetrating the armour of enemy ships. The HMS *Prince George* also carried a secondary battery of 12 quick-firing .40-calibre guns.

Steel armour
The ship was reinforced with 22.9cm (9in) of Harvey armour, which provided it with equal protection for less weight. As a result, the pre-dreadnought ships benefited from a lighter belt than any previous battleships without any loss in protection. The battery, conning tower and deck were also protected by thick steel.

slavery and subjugation – largely supported this choice. Facing the prospect of imminent war with the strongest nation on the planet, Russia agreed to peace talks and, thanks in part to the charisma and negotiation skills of Disraeli, agreed to stop their advance on the Middle East.

Imperial spirit rushed through the public as the might of British muscle flexed and proved itself again. As the empire continued its steady expansion across the continent it came face to face with the most powerful African nation: the Zulus. The British, with a bloated ego, underestimated the strength of their spear-wielding enemies and suffered a crushing initial defeat. In the end it took 16,000 British reinforcements to prise the Zulus' independence from their grip. Expecting to return to a wave of praise for their daring exploits, the victorious army was surprised to discover that British opinions were changing once again.

Gladstone, the "half-mad firebrand", as Victoria dubbed him, preached his outraged opinions about the mass slaughter of Zulus and rampant destruction of their homes. Victoria was furious, but the public sided with Gladstone and, much to the queen's dismay, the power of the government switched hands once more. Liberal leader or not, all of Europe's attention was firmly fixed on Africa as nations began a scramble to establish colonies there. In amongst this mad rush to establish new territory by European powers it was arguably one man's actions that would determine the fate of Victoria's empire.

Led by Muhammad Ahmed, revolution was tearing through the Sudan as tribes rose against their corrupt rulers. As this holy war drew uncomfortably close to the Suez Canal, Victoria urged Gladstone to utilise the British troops stationed there to defend it. The liberal leader refused. In order to buy time he sent one man, General Charles Gordon, to secure the evacuation of loyal civilians and soldiers.

Like Livingstone, Gordon was a national hero. He was brave, dashing, popular and his decorated military career had painted him in the British public's eyes as a gleaming knight of old. Despite these qualities Gordon was also wild and unpredictable. When he reached the Sudan he was horrified by the slavery rife in the region and decided to face the Mahdi in battle. With limited forces, Gordon soon found himself besieged in the city of Khartoum. His appeals for aid, to the adoring public's outrage, fell on deaf ears in the government. It took more than eight months of public fury to finally force Gladstone's hand, but it was too late – Gordon, the nation's hero of Christianity, was dead.

In an instance the liberal vision was shattered, Gladstone was voted out and his moral influence departed with him. The renewed crusading spirit of British imperialism found its poster boy in a man who would lead the empire down a dark and dangerous path. Moving from England to Africa to work on a cotton farm, Cecil John Rhodes had become fantastically wealthy from the diamond rush, but he wanted more – the whole of Africa. Driven by greed and lust for power, Rhodes wished to create a British colony across Africa, not for the betterment of its

▶ The Great Exhibition of 1851 boosted Britain's national confidence people or to spread Christian values but for profit and business.

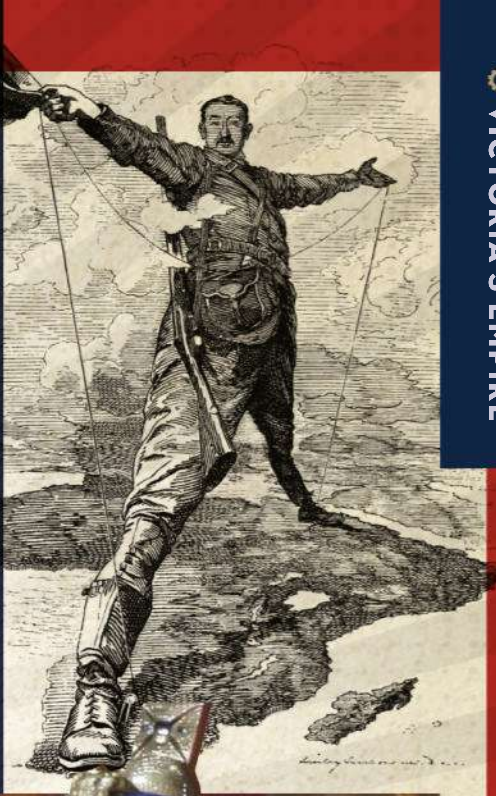
Using the tenacity and cunning that had elevated him to success, Rhodes tricked and butchered his way across the continent, with the British Government backing him every bloody step of the way. Rhodes made it his purpose to make the world English and famously said: "If there be a God, I think that what he would like me to do is paint as much of the map of Africa British Red as possible."

His path of colonial greed led Britain head-first into a conflict now known as the Boer Wars.

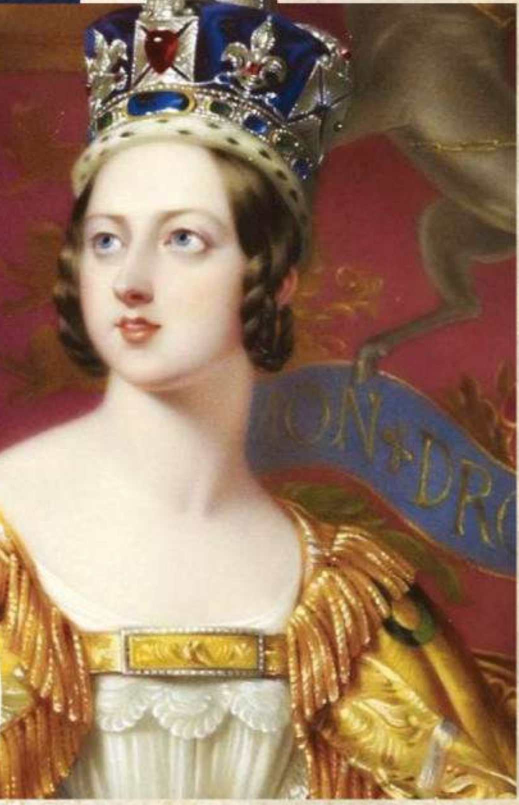
Gold had been found in Transvaal in northern South Africa and Rhodes worried that this would prompt an alliance with the Germans, thus cutting off his route to the north of the continent. Rhodes planned an uprising to overthrow the Boer leaders, but it did not go as he had hoped. Far from the naked, spear-wielding foes he had previously conquered, the Boers had guns, and they fought back hard with skill and courage.

Outrage rippled across Europe at what was seen by many as an unprovoked attack on an independent state, but not in Britain. Fully convinced of their noble

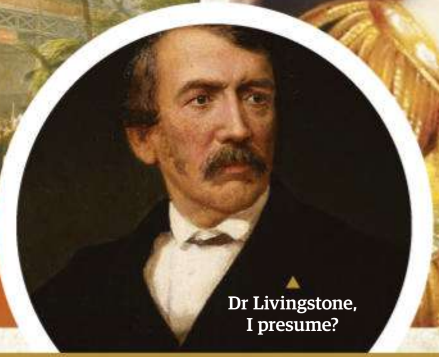
> **"THEY BELIEVED THE BRITISH CAUSE WAS TO EXPORT NOT ONLY TRADE BUT ALSO GOSPEL VALUES OF MORALITY AND JUSTICE"**



This 1892 caricature of Cecil Rhodes was published after he announced plans for a telegraph line and railroad from Cape Town to Cairo, Egypt



Paintings of Victoria in her youth are a world away from the traditional austere depiction of her



Dr Livingstone, I presume?

MAIN COMPETITORS

Three countries that were battling with Britain for territory

RUSSIA

As Britain expanded its territory, so did Russia. For a hundred years Russia expanded east and south, narrowing the gap between the British and Russian empires in Central Asia. Britain soon became obsessed with protecting India, which was a rich source of goods and manpower. The competition for dominance of the states that separated them – Iran, Afghanistan and Tibet – became commonly known as The Great Game. The possibility of a Russian attack (which in reality was unlikely) led Britain into largely unnecessary military involvement in Afghanistan and Tibet.

GERMANY

From 1850 onward Germany began to industrialise at an astonishing rate, transforming from a rural nation to a heavily urban one. In the space of a decade Germany's navy grew massively and became the only one able to challenge the British. Although the German Empire of the late 19th century consisted of only a few small colonies, the newly unified state slowly moved towards colonial expansion in Asia and the Pacific. As Wilhelm II rose to power his aggressive policies in achieving a 'place in the Sun' similar to Britain was one of the factors that would lead to WWI.

FRANCE

Britain's age-old rival France was still licking its wounds after the loss of most of its imperial colonies in the early part of the 19th century. However, French leaders began a mission to restore its prestige in 1850, seeking to claim land in North and West Africa as well as in Southeast Asia. Despite the defeat of France in the Franco-Prussian War, it still continued with zeal to expand its empire, acquiring land in China and all over Africa. Unlike most of its rivals, France would continue expanding after WWI, doing so well into the 1930s.

7 EYE-WATERING EMPIRE FACTS

458 million
people ruled over

23% of the world's surface was ruled by Britain

13.01 million
square miles of land belonged to the empire

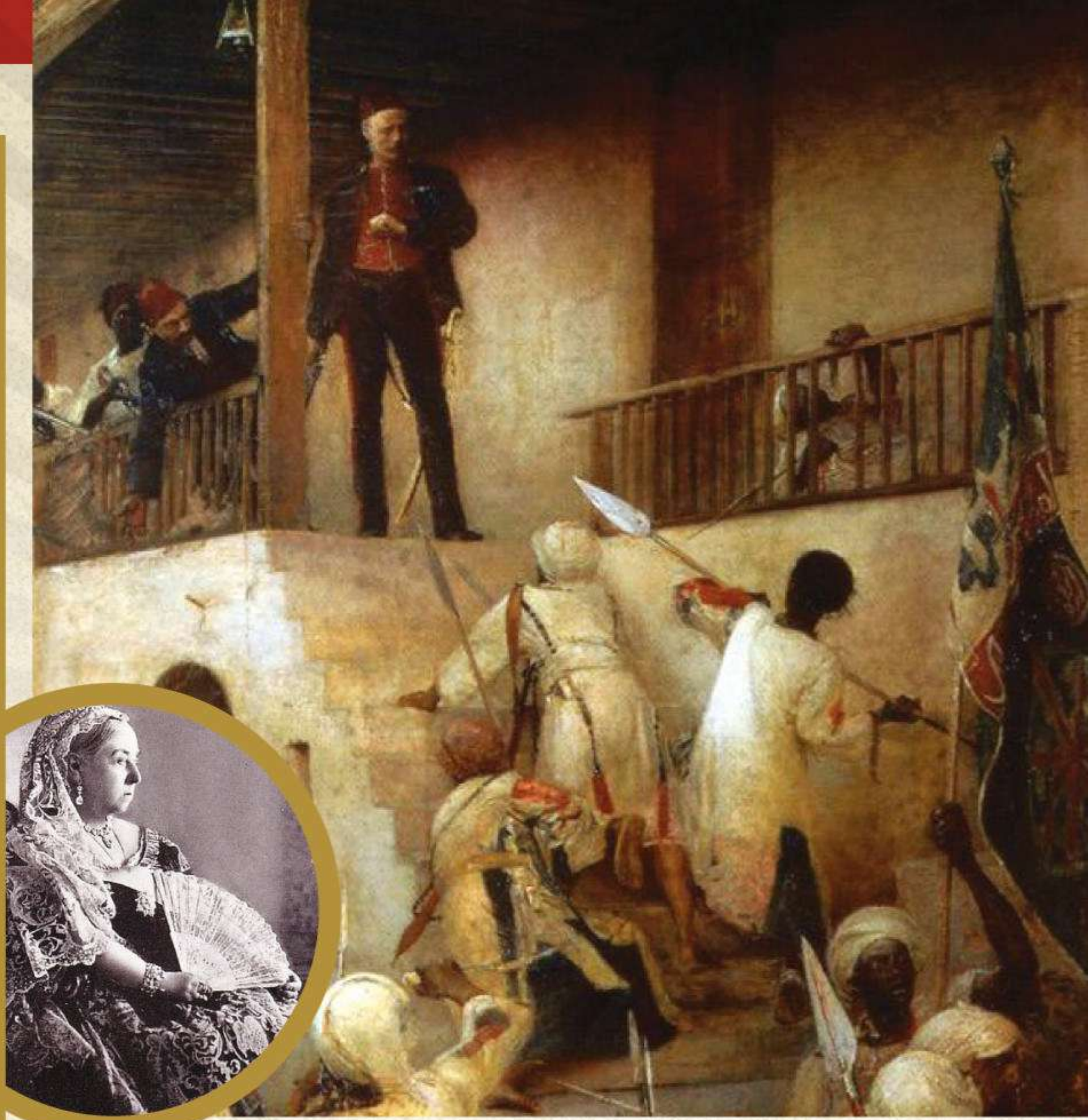
113
SHIPS IN THE ROYAL NAVY

63 years & 21 days
the length of Victoria's reign

165,000
convicts sent to Australia

7,010,000
total goods shipped by Britain in one year (1881)

© Alamy, Getty



mission, the British people believed the Boers to be vicious and uncompromising. More soldiers poured into the region into a war they believed would be short and glorious, but as more British bodies piled up – Victoria's own grandson among them – British confidence in their own unconquerable might began to wane.

As British reinforcements continued to flood into the territory the tide slowly began to turn. Rhodes had managed to squeeze a win from the jaws of defeat, and the Boer territories became British colonies. The empire had grown, but at a cost. Rhodes' controversial actions during the war, including forming what would come to be known as the first concentration camps, had been a step too far for the British public. What had begun as a noble quest of Christianity had transformed into a greedy and brutal scramble for power. When Rhodes died his merciless version of imperialism was buried with him in the dry African dirt.

When Victoria passed away she was finally rid of the black mourning clothes she had worn for 40 years and was dressed entirely in white. Spring flowers were scattered around her body and her wedding veil was placed on her head as she prepared to reunite with the dearest love of her life. She was, however, leaving another behind; the empire she had mothered now stretched across the globe, with large parts of maps of the world coloured in the pink that showed British rule. As the Sun set on the quiet room in which she lay in Osborne House, it was rising on the spice markets of India, and soon the vast plains of British land in Africa would be bathed in golden light. Victoria had died, but the legacy she left behind stretched over the entire planet.

> “THE MONARCHY AND GOVERNMENT BECAME UNITED IN PURSUIT OF ONE GOAL – THE EXPANSION OF THE EMPIRE”

▲ General Gordon organised a year-long defence of Sudan, but a relief force arrived two days after the city had fallen and he had been killed

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THE PARSONS STEAM TURBINE

How this Victorian generator made steam the driving force behind power production around the world

The steampunk science-fiction sub-genre depicts an alternative reality in which modern devices run on gaseous water. This isn't as far-fetched is it might sound, because roughly 80 per cent of Earth's power stations generate electricity using steam-driven turbines. Appropriately, we have Victorian engineer Sir Charles Parsons to thank for that, as it was his energy and imagination that turned a device dating back to the 1st century CE into something capable of converting H2O into power on an industrial scale.

Steam turbines operate on a similar principle to those driven by wind: molecules in a fluid rotate angled blades and produce mechanical energy that can be converted into electrical energy by a dynamo. Instead of meteorological forces providing the thrust, however, it is the impact of pressurised steam emitted from nozzles (impulse turbines) or the change in the pressure of the steam as it expands (reaction turbines).

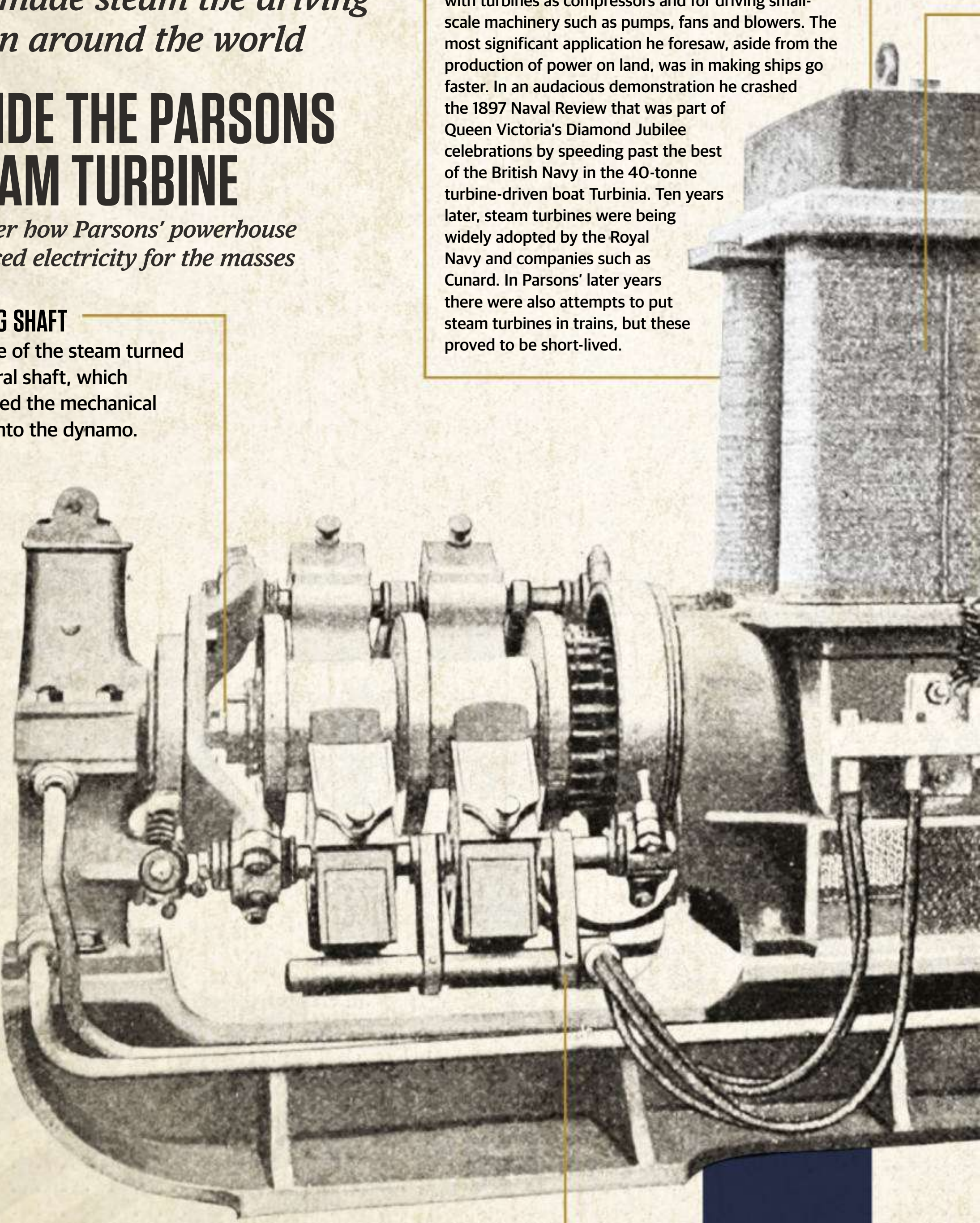
In Parsons' turbine, water was converted to steam by burning coal. The steam was then literally squeezed into one or more drums containing a series of disc-like rotors attached to a rotating shaft. The perimeter of each rotor was fitted with brass blades designed to receive the force of the steam at high speed without shattering or divert it so that it struck the next set of blades at the proper angle. Successive rotors were fitted with longer blades to expand their diameter and accommodate the increasing volume of the cooling steam.

Parsons' greatest achievements were making the advances needed to boost the power output and efficiency of steam turbines. These included inventing a special bearing that allowed the rotors to turn at much faster speeds. His basic design is still used today, and because of that the vision of a society dependent on steam is fact, not fiction.

INSIDE THE PARSONS STEAM TURBINE

Discover how Parsons' powerhouse produced electricity for the masses

ROTATING SHAFT
The force of the steam turned the central shaft, which transferred the mechanical energy into the dynamo.



STEAMING AHEAD

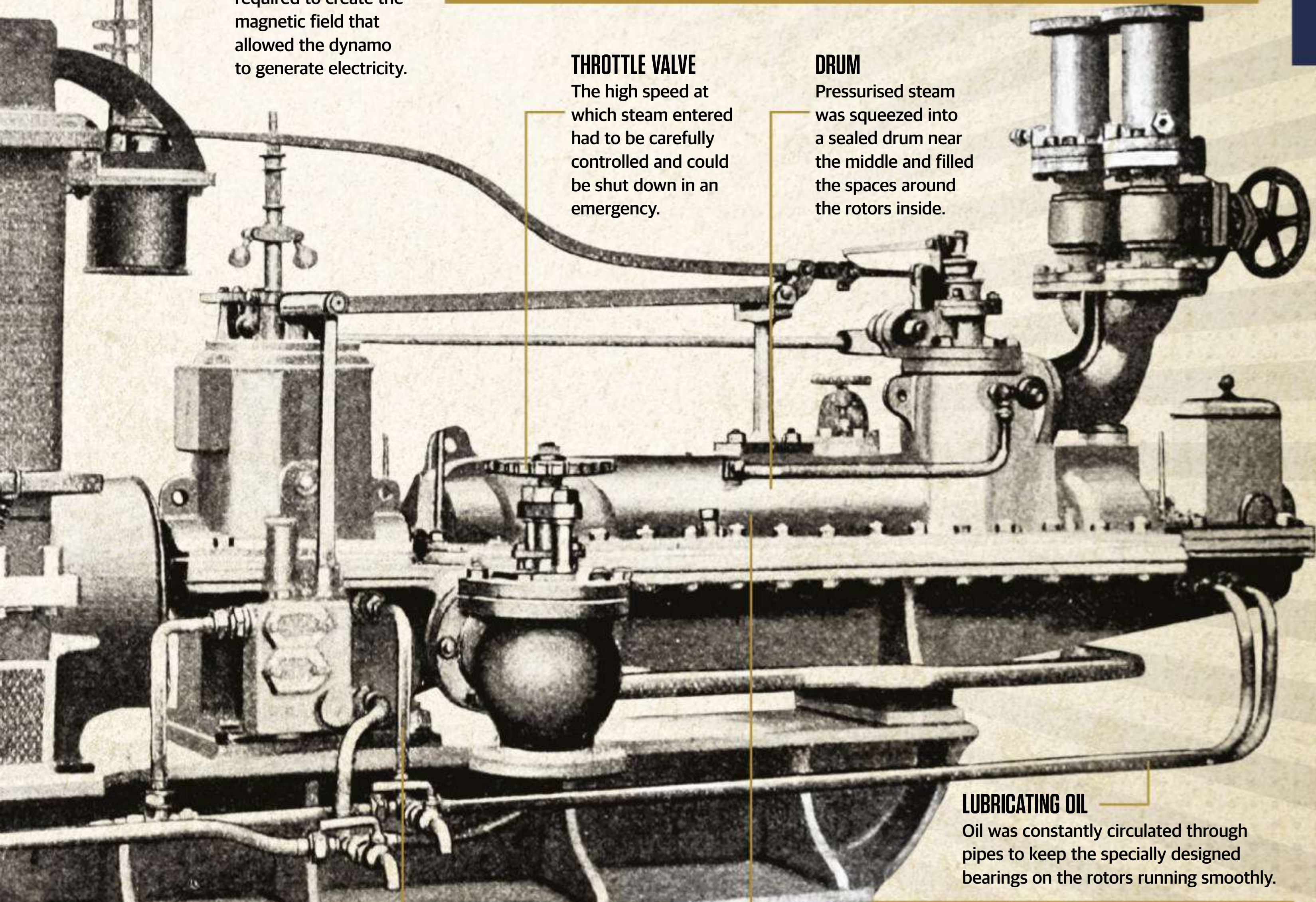
Parsons saw potential in his prime mover in places other than just power stations. He also experimented with turbines as compressors and for driving small-scale machinery such as pumps, fans and blowers. The most significant application he foresaw, aside from the production of power on land, was in making ships go faster. In an audacious demonstration he crashed the 1897 Naval Review that was part of Queen Victoria's Diamond Jubilee celebrations by speeding past the best of the British Navy in the 40-tonne turbine-driven boat Turbinia. Ten years later, steam turbines were being widely adopted by the Royal Navy and companies such as Cunard. In Parsons' later years there were also attempts to put steam turbines in trains, but these proved to be short-lived.

DYNAMO
The mechanical energy generated by the turbine was converted into electrical energy in an attached dynamo.

▶ The HMS *Dreadnought* was the first capital ship (leading battleship) in the Royal Navy to run on steam turbines

WHO WAS SIR CHARLES PARSONS?

Charles Algernon Parsons was born in London on 13 June 1854. He was the youngest son of Irish astronomer William Parsons, the Third Earl of Rosse, who served as president of the Royal Society. Parsons graduated from Cambridge in 1877 with a first-class degree in mathematics and mechanics. He finished his first turbine seven years later and subsequently founded companies to develop his turbo-generator designs. He would go on to set up the Marine Steam Turbine Company, which built turbines for battleships such as the HMS *Dreadnought*. Parsons became a fellow of the Royal Society in 1898 and was knighted in 1911. He died on 11 February 1931 in Jamaica.



MAGNET
A large magnet was required to create the magnetic field that allowed the dynamo to generate electricity.

THROTTLE VALVE
The high speed at which steam entered had to be carefully controlled and could be shut down in an emergency.

DRUM
Pressurised steam was squeezed into a sealed drum near the middle and filled the spaces around the rotors inside.

LUBRICATING OIL
Oil was constantly circulated through pipes to keep the specially designed bearings on the rotors running smoothly.

GUIDE AND MOVING BLADES
Inside the drum the pressurised gas moved across brass blades fitted to the rotors that turned the shaft.

TURBINE
Parsons' steam turbine generated mechanical energy by using steam to drive a series of bladed rotors on a rotating shaft.

LONG LIVE THE REVOLUTION

The Industrial Revolution brought the world its greatest opportunities but also its biggest challenges

Written by Cris Andrews

Nottingham, 1788, and after lots of hard work, mechanical engineer James Watt has made a great breakthrough - he has patented a throttle valve to control the power of his steam engine and a centrifugal governor that will regulate steam flow into the piston in order to keep the engine's speed constant.

It's the latest in a long line of improvements Watt has made to his engine. Over subsequent decades the technology will be adapted and improved by other engineers. It will transform industry, facilitate mass production and distribution and help make sustained, rapid economic growth possible.

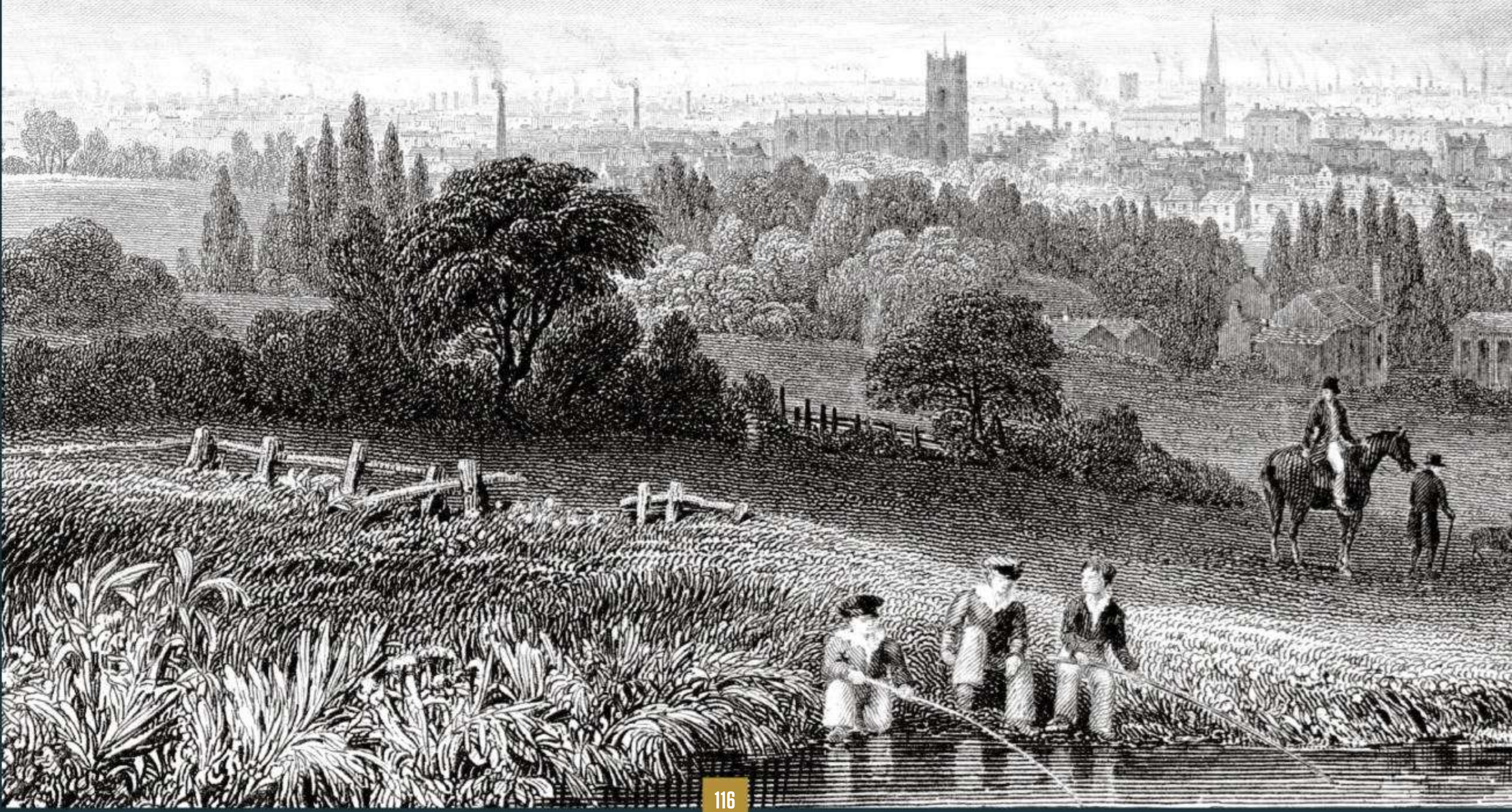
Fuelled by relentless technological innovation and progress, the Industrial Revolution first spread across Britain, then into Europe, the Americas and eventually all around the world. As a result, more people in the industrialised countries would have more wealth than ever before.

But the Industrial Revolution would also unleash forces that would threaten the very fabric of society, dynamics that would set people against each other in a scramble for money, status and power. Eventually, these processes would pit the nations of Europe against each other in two devastating wars that would not be contained to the continent, conflicts that would claim millions of lives.

Today, lives, communities, nations and international relations are still shaped - for better or worse - by the forces that were unleashed way back in the middle of the 18th century.

SOCIAL MISERY

Whitechapel, London, and 100 years after Watt's breakthrough, a man stands in the shadows with murder on his mind. His feelings of contempt for the filthy wretches that live in this place - Outcast London he calls it - are as sharp as the murderous implements in his little black bag. He has killed before, three times, prowling the streets, ale houses and slums in search of prey. The papers, in their characteristic hysteria, have given him a suitably gruesome moniker, spilling ink as readily he does blood to decry the police for their failure to catch him. But Jack the



“GOVERNMENTS WOULD BRING IN REFORMS TO GUARD AGAINST THE EXCESSES OF INDUSTRIAL CAPITALISM”

Ripper - he laughs at the name - will not be caught. He will never be caught.

It's the autumn of 1888, and as the wealthy recover from a busy social season, the newly rich buy distracting trifles and frequent art galleries, and the more prosperous workers have better food on their tables than ever before. In the back streets of Whitechapel, however, the 'Ripper murders' of August to November 1888 focus the nation's attention on the plight of those people that the Industrial Revolution has left behind.

Only in a place where thousands huddle together in doss houses, taverns and on street corners, and where women and children are used as prostitutes, could such atrocities be conceived. And only in a place where the police are more concerned with public order than investigating crime - unless there's a convenient foreigner around to fit up - could the Ripper murders go undetected.

For well-to-do Londoners, the 'wicked mile', as social reformers called the area where the Ripper killed his victims, was full of undesirables, drunks, foreigners, prostitutes and criminals. “Always carry a firearm east of Aldgate!” Sir Arthur Conan Doyle had Sherlock Holmes say.

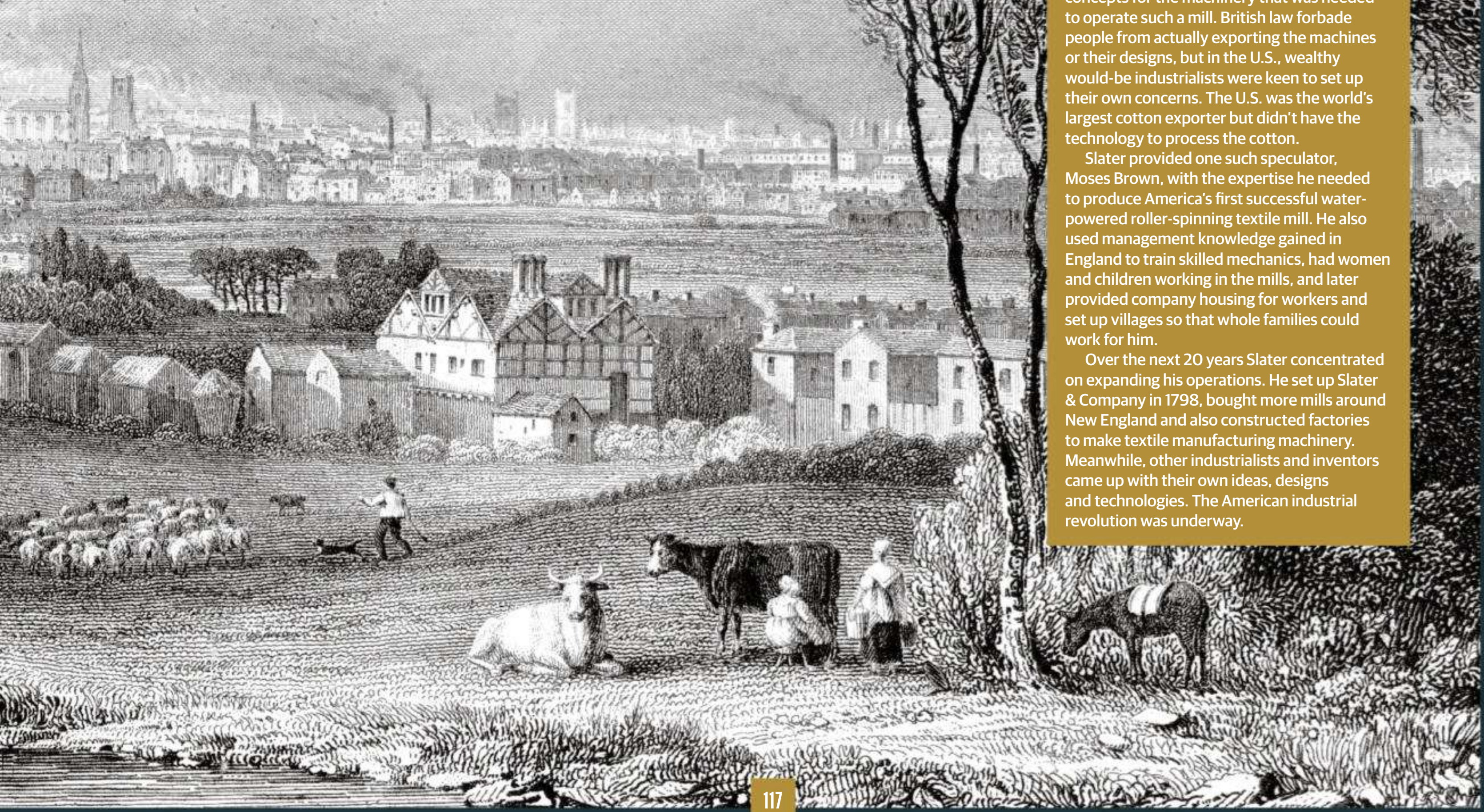
In the year's following the Whitechapel murders governments passed legislation in order to improve living conditions, sewage and rubbish collections. Future governments would bring in more reforms to guard against the worst excesses of industrial capitalism.

COMMON PROBLEM

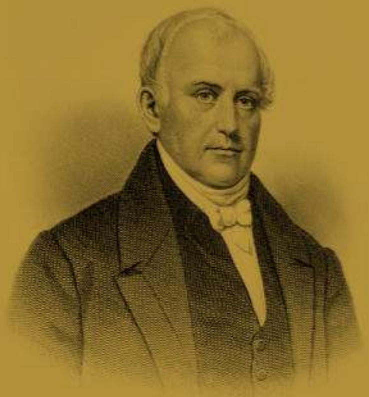
In November 1842, the sort of poverty that shocked the world in Whitechapel was more widespread in English cities. This was the year Friedrich Engels' father sent him to Manchester to work in the family cotton mill.

Engels' father hoped the move would keep his boy away from the radical friends the younger man had made at home in Germany. However, Manchester back then was a burgeoning industrial town and Engels witnessed first-hand the squalid living conditions, disease, child labour and dangerous working practices prevalent across Britain.

Engels' famous study, *The Condition of the Working Class in England*, was based on these observations. He theorised that the processes of industrialisation and mass-production economies were oppressive and exploitative and would inevitably produce what he called “social misery”. This study was to become one of the most significant social



SAM THE SLATER: TRAITOR OR TYCOON?



An 18th-century mill with a cream façade still sits off the Blackstone River in Pawtucket, Rhode Island, just north of Providence. Once a working mill, it's now a museum and a National Historic Landmark, testament to the man who designed the machines that made it work way back in 1793. That man was Samuel Slater, who was hailed in the U.S. as the founding father of the American industrial revolution while being simultaneously slammed as 'Slater the Traitor' by many in Britain.

This mill was the first in America to use British textile technology. Slater, an apprentice to a Derbyshire mill owner, emigrated to America in 1789, memorising the design concepts for the machinery that was needed to operate such a mill. British law forbade people from actually exporting the machines or their designs, but in the U.S., wealthy would-be industrialists were keen to set up their own concerns. The U.S. was the world's largest cotton exporter but didn't have the technology to process the cotton.

Slater provided one such speculator, Moses Brown, with the expertise he needed to produce America's first successful water-powered roller-spinning textile mill. He also used management knowledge gained in England to train skilled mechanics, had women and children working in the mills, and later provided company housing for workers and set up villages so that whole families could work for him.

Over the next 20 years Slater concentrated on expanding his operations. He set up Slater & Company in 1798, bought more mills around New England and also constructed factories to make textile manufacturing machinery. Meanwhile, other industrialists and inventors came up with their own ideas, designs and technologies. The American industrial revolution was underway.

critiques of industrialisation and heavily influenced the work of Karl Marx, with whom Engels co-authored *The Communist Manifesto*, published in 1848.

BRITAIN CHALLENGED

In 1850, Britain produced two-thirds of the world's coal and half the world's cotton, textiles and iron. It would not hold on to its pre-eminent industrial position much longer, though.

Towards the end of the 18th century the U.S. had begun to industrialise, as had northern Europe, including France, and later, Germany. Towards the end of the 19th century these countries would begin to compete with Britain, with some eventually surpassing her in the global industrial economy in the 20th century.

Industrialisation first happened in Europe in places where governments gave financial inducements to manufacturers and industrialists to adopt mechanical systems. Where wages were high, factory owners had an incentive to bring in machines to reduce labour costs.

There were other reasons. Industrial espionage was rife in Britain; many industrialists sent their sons to Europe on apprenticeship and some British entrepreneurs, like William Cockerill and his son John, relocated to the continent and took their ideas with them. The Cockerills ended up in Belgium and have been credited with kick-starting the industrial progress in that country.

Political changes in Europe fuelled the pace and scale of industrialisation, in particular the rise of nationalism as a unifying force in the Italian and German states and as opposition in the huge multi-national empires of Eastern Europe. In the late 19th century, Germans, French and others challenged British interests in colonial markets. All over the continent, military leaders embraced new mechanical weapons and devised plans to use them.

Eventually there would be a terrible world war that would see around 40 million killed. Sadly its horrors failed to prevent the rise of extremist governments in Russia and Germany, and in 1939 the world was plunged back into the fires of war, the worst clash of arms in history.

▲ A Chartist meeting on 10 April 1848 at Kennington Common, by William Edward Kilburn

▶ Dorset Street, Miller's Court, Whitechapel, London, taken in 1902, 14 years after the Ripper murders ended

(Top left) A portrait photograph of Friedrich Engels from May 1877

THE WORKING CLASS MOVEMENT

As far back as the Middle Ages, workers have joined together to protect their interests. Employers and governments – who relied on cheap labour for their wealth – had always found this disruptive and objectionable, particularly when trade union members downed tools and went on strike. In the late 18th century, with people pouring into British cities, more skilled workers were joining forces to protect their interests.

In 1800, the Pitt government banned trade unions. Britain would spend much of the next 15 years at war with France, and the government was worried that groups of workers, under the influence of Jacobins and other revolutionary sympathisers, would take advantage and strike during times of conflict, thereby undermining the war effort.

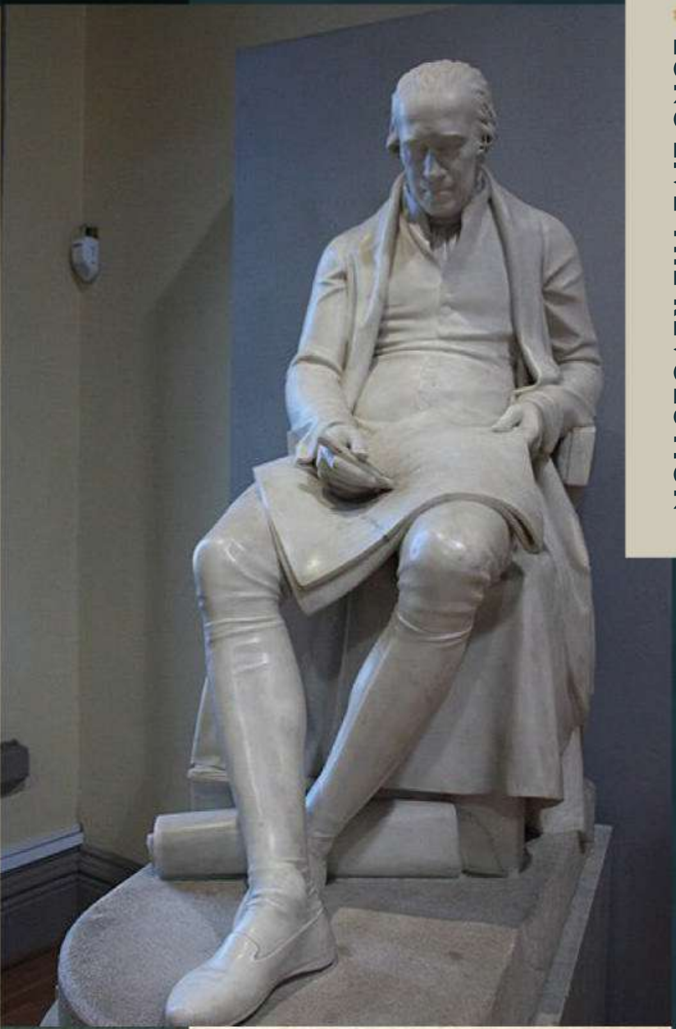
> **"GOVERNMENTS WERE CHOSEN BY THE RICH AND PASSED LAWS AND PURSUED POLICIES THAT FAVOURED THE RICH"**

Pitt's anti-union laws were repealed in 1824, but severe limitations on rights to strike remained. It wasn't until 1871 that trade unions could operate without major restrictions. The Thatcher government re-introduced restrictions on trade union activity in the 1980s.

During the 18th and 19th centuries, Britain's ruling elite was also concerned about the politicisation of organised workers' movements. In the mid-18th century, men could only vote if they owned a certain amount of land, and women couldn't vote at all. Just three per cent of the British population was eligible to vote in the 1831 election. Governments were chosen by the rich and consequently passed laws and pursued policies that favoured the rich.

The Chartists were an early workers' movement who stood for universal suffrage – for men at least. Named after the People's Charter produced in 1838 by members of the London Working Men's Association, the Chartists also wanted secret ballots, equal-sized constituencies and an end to property qualification for MPs, which would enable working men to stand for Parliament.

Over the next ten years this group organised public meetings, a national convention, and even established local periodicals, such as the *Northern Star* and *Leeds General Advertiser* to advertise meetings and promote their causes.



A statue of James Watt, steam engine pioneer

Three times the Chartists served petitions to Parliament, the second one containing 3 million signatures. All were ignored. In 1848, Parliament shut down the group's National Land Company, which had been set up with funds donated by shareholders to buy land on which the shareholders could live and work. Presumably it had to be shut down because it would have otherwise

THE MERTHYR RISING

The people of Merthyr Tydfil had been suffering for too long. Wages in this Welsh town had been low since anyone could remember, working conditions were intolerable and property was too often taken by the authorities to cover workers' debts. Some miners were being paid with vouchers that they could spend only in their master's shops. Those who asked for better conditions had their wages docked even further.

By the 1830s, Merthyr's rich natural reserves of iron ore, coal and limestone deposits were in enormous demand. South Wales was producing 40 per cent of British pig iron. But while bosses got rich, their workers languished in poverty.

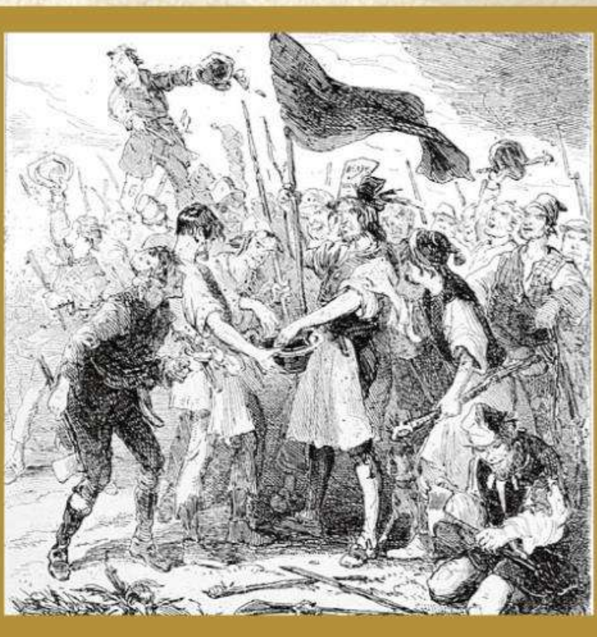
Tensions had simmered for years, and in May 1831 the situation boiled over when workers from the Cyfarthfa Ironworks went on strike. Unrest spread to nearby villages, and by 1 June the whole region was in revolt.

Between 7,000–10,000 workers took to the streets to call for change, marching under a plain red flag – the first time the historical symbol of revolt had been used to demonstrate workers' power. When the government despatched soldiers to restore order many of the strikers armed themselves and drove the soldiers out using guerrilla tactics and roadblocks.

Refusing to back down, on Sunday 6 June, the authorities sent armed soldiers to the site of a mass meeting and the protestors were finally dispersed, ending the uprising.

The government struck back hard, imprisoning many rebel leaders and sending others to Australian penal colonies. One striker, Richard Lewis (known locally as Dic Penderyn), was hung for stabbing a soldier despite no evidence of his supposed crime being presented.

Despite the crackdown the uprising inspired workers to set up trade union lodges around Wales. Together they knew they were stronger. Dic Penderyn became a martyr, a symbol for those who would resist oppression and continue the struggle. In the iron capital of the world, the Welsh working class had arrived.



made these people eligible to vote and stand for Parliament, a grave threat to the established order.

In 1839, Chartists led a failed uprising against the authorities in Newport, Wales that led to mass arrests. Three years later workers went on strike in 22 counties across England and Scotland demanding higher wages and, in some places, adherence to the People's Charter. The strikes had not been organised by Chartists, but many Chartist leaders were still arrested and hundreds of supporters were imprisoned.

In 1848, with uprisings happening across Europe, the Chartists tried one last time to petition the government. In response the government enacted an old law that prevented more than ten people presenting a petition and quickly passed legislation making what they called 'attempting to intimidate Parliament' a criminal offence.

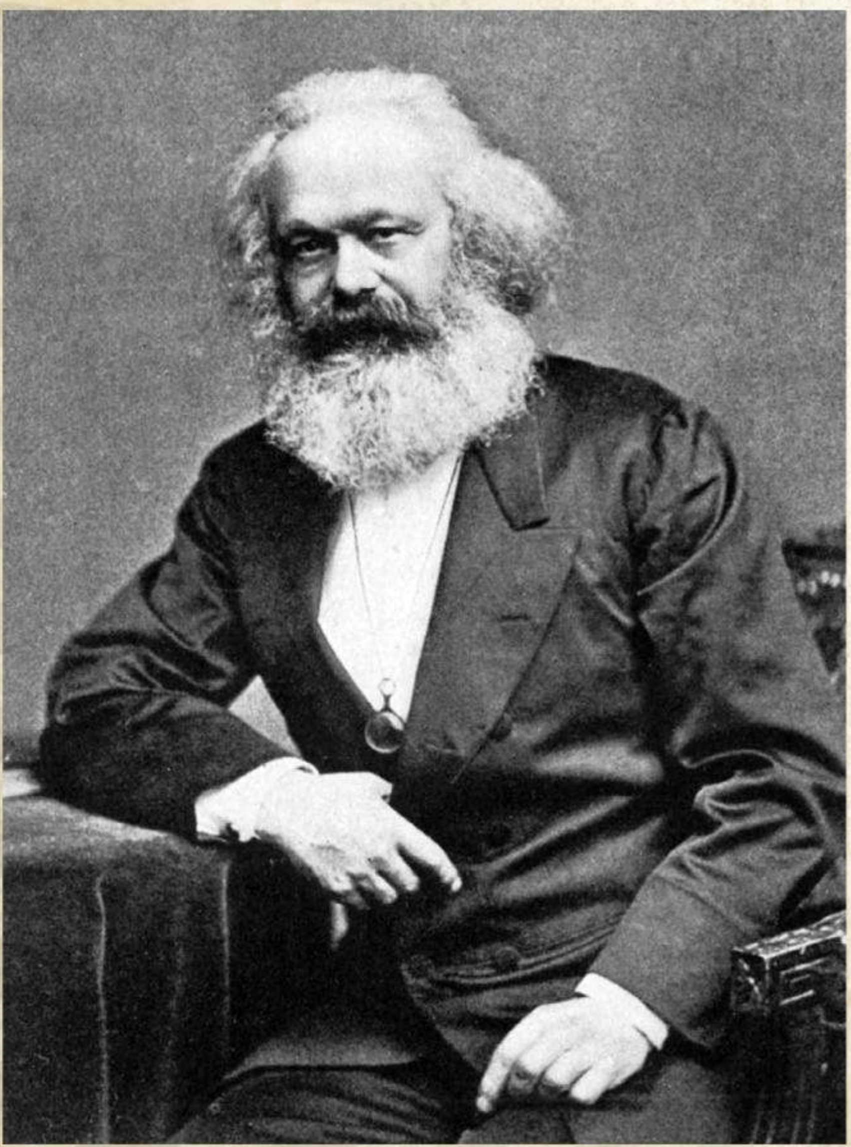
After this the movement began to fall apart. Governments were steadfast in their opposition and Chartist leaders disagreed over using violence to achieve objectives and whether the movement should align with middle-class radicals. However, that is not to say that legacy of the Chartist movement is one of failure. Far from it.

While the Chartists began to fade away, five of their six key demands were in fact gradually adopted. In 1867, the Second Reform Act was passed into law, doubling the number of men who could vote to 2 million. The following year this was amended to allow all men who were the heads of their household to vote.

SOCIALISM REJECTED

Karl Marx theorised the industrial capitalist system would destroy itself and be replaced by a socialist state. However, in Britain the ruling elite periodically bought off moderate reformists, marginalising radicals, maintaining the system and thwarting the revolution.

On the continent things were different. European monarchs still ruled in most parts and were less likely to agree to moderate demands. They also tended

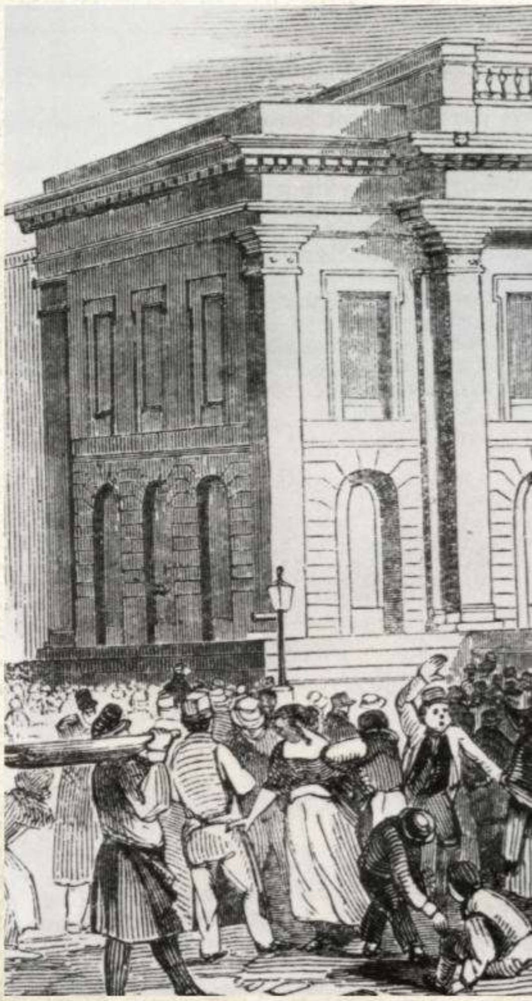


Karl Marx's vision of capitalism collapsing in on itself is yet to happen

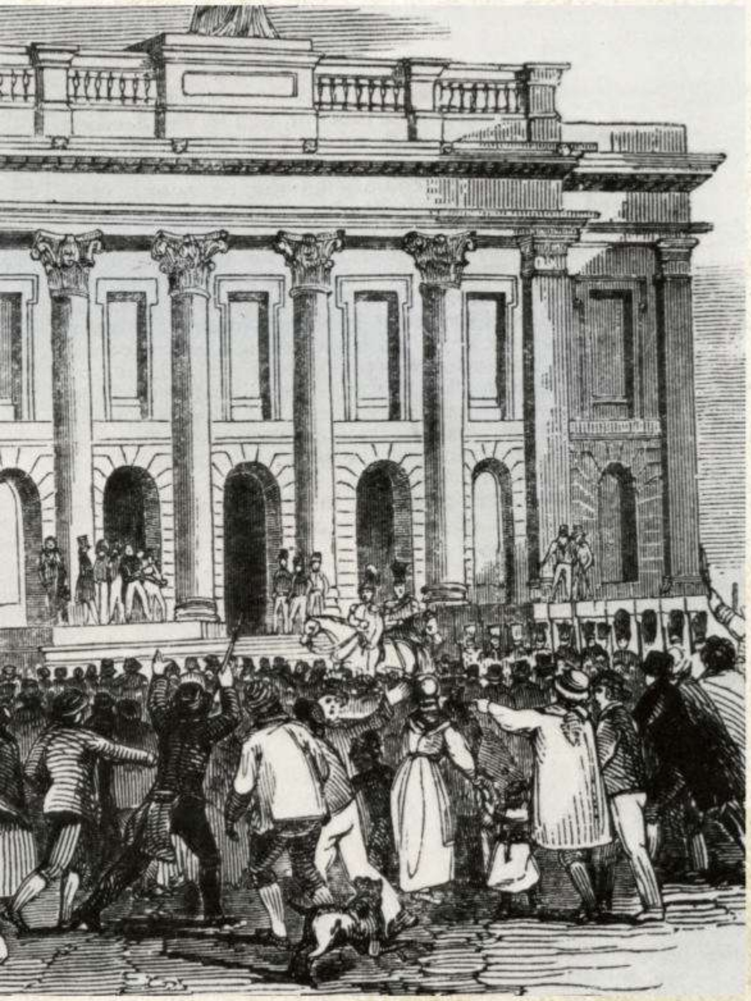
JOHN
COCKERILL

A statue and tomb of industrialist John Cockerill in front of the City Hall of Seraing in Belgium

(Far right) Keir Hardie, founder of the Labour Party, rails against WWI during a speech in Trafalgar Square, London, in 1914



This illustration depicts an industrial riot in Manchester in 1842



“IT WOULD TAKE ANOTHER WORLD WAR BEFORE THE BRITISH PEOPLE VOTED IN A MAJORITY SOCIALIST LABOUR GOVERNMENT”

to use their soldiers to suppress civil disobedience with barely concealed savagery and contempt.

Socialist thought was more acceptable in France, with its revolutionary and libertarian traditions. Meanwhile, in the U.S., huge trade unions formed.

In the late 19th century, socialist politicians started to appear in the British Parliament. The Liberal Party shifted to the left, albeit only slightly, and in 1893, Keir Hardie, a former Liberal politician, formed the first Labour Party with support and funding from trade unions.

It wasn’t until shortly after the First World War that all British men were allowed to vote, and this was only conceded because British elites had seen revolution in Russia and feared that something similar could happen in Britain after the hardships of war and the Spanish flu epidemic. It would be another ten years before all women would be allowed to vote.

By then the electorate had already returned the first Labour government. MacDonald’s 1924 administration didn’t enjoy a majority in Parliament, though, and lasted only nine months before the Conservatives were back. MacDonald became PM for a few months in 1931, again with no Parliamentary majority. That year he left the Labour Party to lead the National Government, which consisted of mainly of Conservative and Liberal MPs. It would take another world war before the British people voted in a majority socialist Labour government that was committed to redistributing wealth and establishing welfare service under Clement Attlee.

This was Britain’s first - and last - socialist government. Since Winston Churchill’s Conservatives returned to power in 1951, Conservative or moderate Labour governments have continued to navigate, protect and nurture the system bequeathed to them in the 18th century.

It seems a staunch belief in hierarchy, status, deference and tradition, along with an aversion to sudden radical change, are aspects of British culture that haven’t changed since the Industrial Revolution. Nor would it seem that British society has lost, in the words of George Orwell, that “primitive patriotism which could be appealed to [by the elites] whenever it was necessary to make them [people] accept longer hours or shorter rations”.

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INSTRUMENTS OF DEATH

Man's ability to harness the true power of steel and fire changed countless lives. It also claimed millions on the battlefield

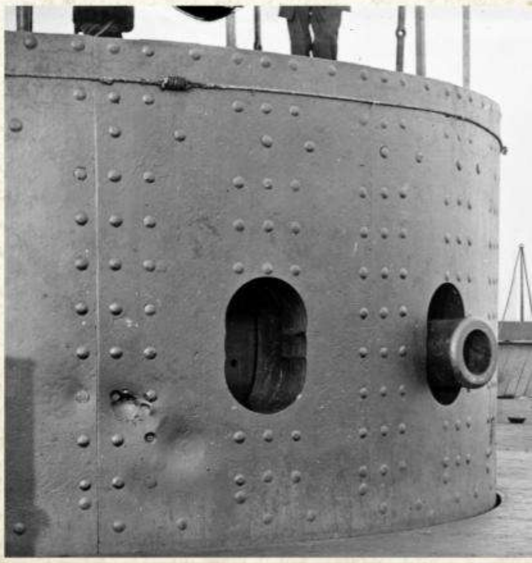
Written by Edoardo Albert

▲ Death was not a new part of war, but the Industrial Revolution made it possible for a new level of carnage and cruelty to be wrought

"Dead horses were everywhere... Men? There were men enough; all dead apparently, except one... He lay face upward, taking in his breath in convulsive, rattling snorts, and blowing it out in sputters of froth which crawled creamily down his cheeks, piling itself alongside his neck and ears. A bullet had clipped a groove in his skull, above the temple; from this the brain protruded in bosses, dropping off in flakes and strings. I had not previously known one could get on [...] with so little brain. One of my men asked if he should put his bayonet through him."

Ambrose Bierce later became well known for his tales of supernatural terror, but he was unfortunate enough to have tasted terror first hand during his service in the American Civil War as a soldier of the Union's 9th Indiana Infantry, notably during the Battle of Shiloh (6-7 April 1862). Death was obviously not something new on battlefields, however, its scale, radius and indiscriminate nature assumed entirely new dimensions during the American Civil War, which raged from 1861-1865. This was war on an industrial level. As such, it was very different to anything that had gone before, even the Napoleonic Wars - the great global conflict that had inaugurated the 19th century.

On 18 June 1815, Napoleon Bonaparte met his Waterloo. The long series of wars that had started with the French Revolution in 1789 and had continued during the rise, apotheosis and fall of Napoleon came to an end, setting the



DEATH TO THE MAX – THE MAXIM GUN

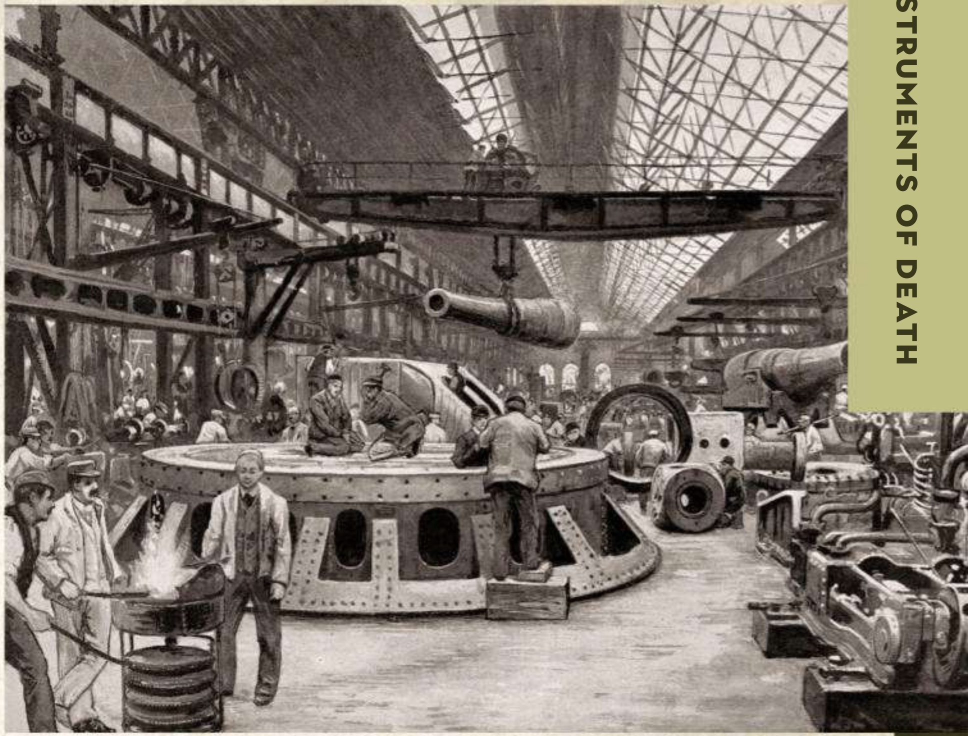
The machine gun made mockery of old ideas of courage and valour, cutting men down like grass

◀ Developed and used with devastating effect in the colonial wars of the 19th century, the machine gun became the defining weapon of the Great War

The first fully automatic machine gun, the Maxim, proved its devastating effectiveness in the Battle of the Shangani on 25 October 1893. Seven hundred men of the British South Africa Police (BSAP) had set up camp on the Shangani River. They were advancing into the territory of the Ndebele people in response to raids ordered by King Lobengula. The Ndebele made a night attack, but the BSAP scouts raised the alarm. They were facing a fierce and disciplined force of some 5,000 Ndebele warriors armed with assegais and rifles, but when the Ndebele charged they were cut down, as if scythed, by the combined fire of the five Maxim guns the BSAP had set up around their camp. The BSAP force suffered only four deaths, while roughly 1,500 Ndebele lost their lives and the army general, Manonda, hung himself rather than return in disgrace and defeat to his king.

The Maxim gun, which could fire a deadly 600 rounds per minute, became a key weapon in the European powers' Scramble for Africa, its firepower proving devastating to local armies. As Hilaire Belloc wrote in *The Modern Traveller*, his satire on colonialism, "Whatever happens, we have got/The Maxim gun, and they have not."

◀ The USS *Monitor* boasted a revolutionary gun design that became the basis for all later battleships: an armoured turret that was able to rotate through 360 degrees



▶ The vast increase in production brought about by the Industrial Revolution caused a huge increase in the destructiveness of the weapons of war

political shape of Europe and the world for the next half century. The men who fought during the Napoleonic Wars, while divided by nation, were generally united by a common code of ethics. For example, a captured officer would give his word of honour not to escape and then be allowed relative freedom. Transport was on foot or hoof, communication was by messenger, muskets fired short-range volleys and cavalry still swirled around the battlefield. Honour, duty, courage and discipline were the watchwords of military training, while war itself was generally confined to the opposing armies – civilians were not a prime target.

Then came the Industrial Revolution. First starting in Britain, it then spread to Europe and America before going round the world, decimating the agricultural, rural societies – where people were spread relatively evenly across countries – and transforming them into urban, technological cultures with people concentrated in rapidly expanding cities. At the beginning of the 19th century the fastest form of transport was the horse. During the Napoleonic Wars scouts operated behind enemy lines, evading capture purely by riding the fastest horse possible. By the end of the century, however, it was a different story. Railways had cut iron lines across Britain, Europe and North America. In 1886, Karl Benz invented the petrol-driven motor car and, three years into the 20th century, the Wright brothers built the first aeroplane. Ships, for centuries reliant on the wind, plied the oceans under columns of smoke, and factories churned out thousands of identical products.

"THE GREAT ADVANCES IN CHEMISTRY DURING THE 19TH CENTURY MEANT THAT EXPLOSIVE SHELLS REPLACED SOLID CANNON BALLS"

The first bolt-action rifles, such as the Dreyse needle-gun, could fire a round every five seconds, making them far more deadly than flintlock muskets, which could fire only three rounds a minute in the hands of the best infantrymen. What's more, the new rifles had 'rifled' barrels that imparted spin to the bullet, making it much more accurate. Couple that with factories able to produce thousands of these new rifles, and armies now had the means to pour out devastating volleys of fire to ranges of 200 metres (656 feet).

New and far more destructive artillery was also developed. The great advances in chemistry during the 19th century meant that explosive shells replaced solid cannon balls. What's more, the perfection of the Bessemer process in 1856 enabled the inexpensive mass production of steel. This meant that artillery barrels could be cast in iron, which resulted in longer and smoother barrels that could fire shells further: artillery was becoming the king of the battlefield.

But it wasn't just weapons that got an upgrade – the development of railways meant that more men could be moved over longer distances and kept supplied than ever before. Married with 19th-century nationalism and conscript armies, and all the elements were present to give those in power the ability to field armies larger than any the world had seen before. The conditions were being set for warfare to enter a new and far more destructive phase.

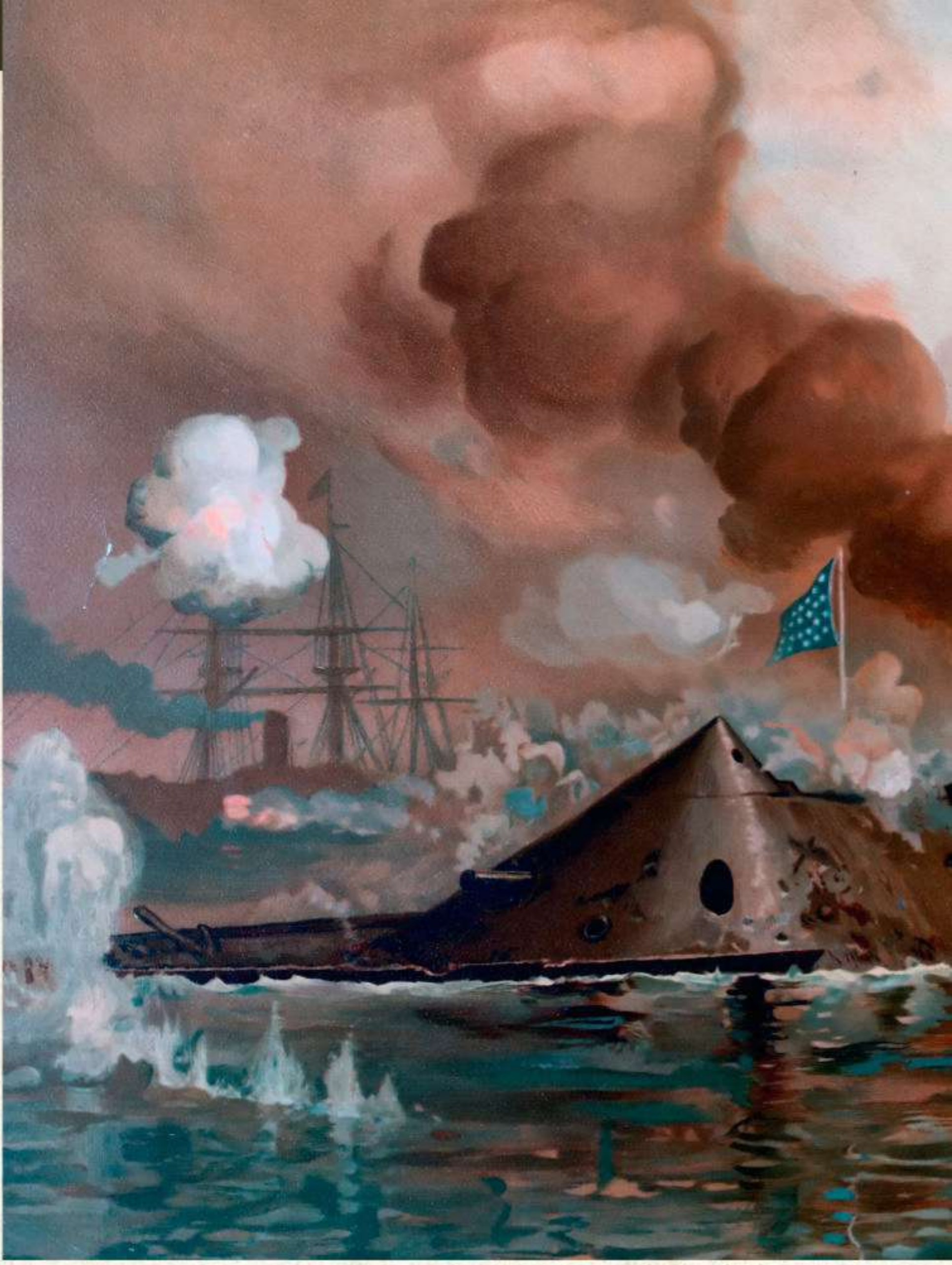
Following the end of the Napoleonic Wars there was peace in Europe for a generation. But as the old soldiers died off, taking with them the memories of war-time carnage, war began to once again assume a certain glamour. The wheels of conflict began to spin, and they first ground up against each other in Crimea – to where war has returned recently. The Crimean War of 1853 to 1856 was the first conflict of the Industrial Age. Its most famous engagement, the Charge of the Light Brigade in October 1854, can be seen as being emblematic of that change: mounted cavalrymen riding into Russian cannon fire. Just as famously, Florence Nightingale and her staff began to professionalise the medical care of wounded soldiers for the first time.

The Crimean War incorporated many new developments: large armies were moved by railway and ship; it saw the first use of explosive shells in battle; and the telegraph was employed both for war communication and by newspaper correspondents reporting on the war for the first time. As such, it was the first truly modern war, and the casualty figures reflected that, with over 500,000 killed.

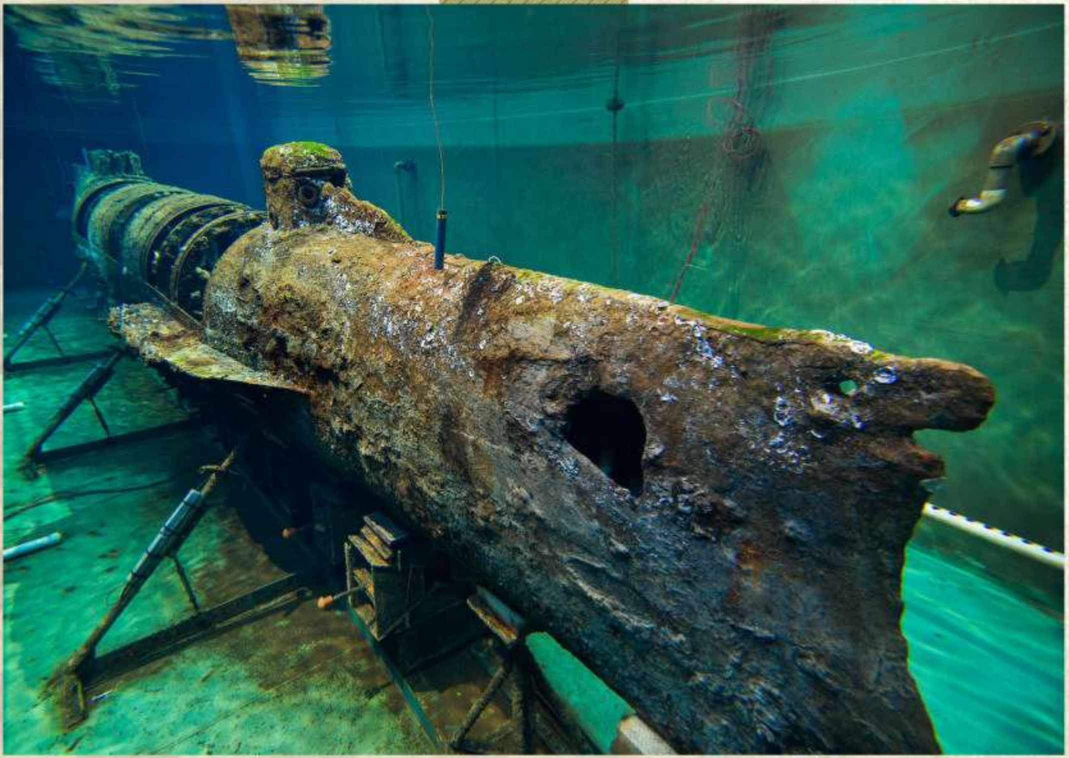
But the thing about progress is that it never stops, and the carnage of the Crimean War was soon overshadowed on the other side of the Atlantic. The American Civil War saw up to a million people killed and countless more injured. It would prove to be the harbinger of industrial warfare in its most absolute sense: total war.

Total war was the logical development of industrial warfare. The complete resources of the state, people and production were turned towards war. As such, what would have previously been considered civilian centres became military targets: factories, railways and ports all came to be seen as part and parcel of the enemy war effort and thus legitimate targets. Even the civilian population became part of the conflict.

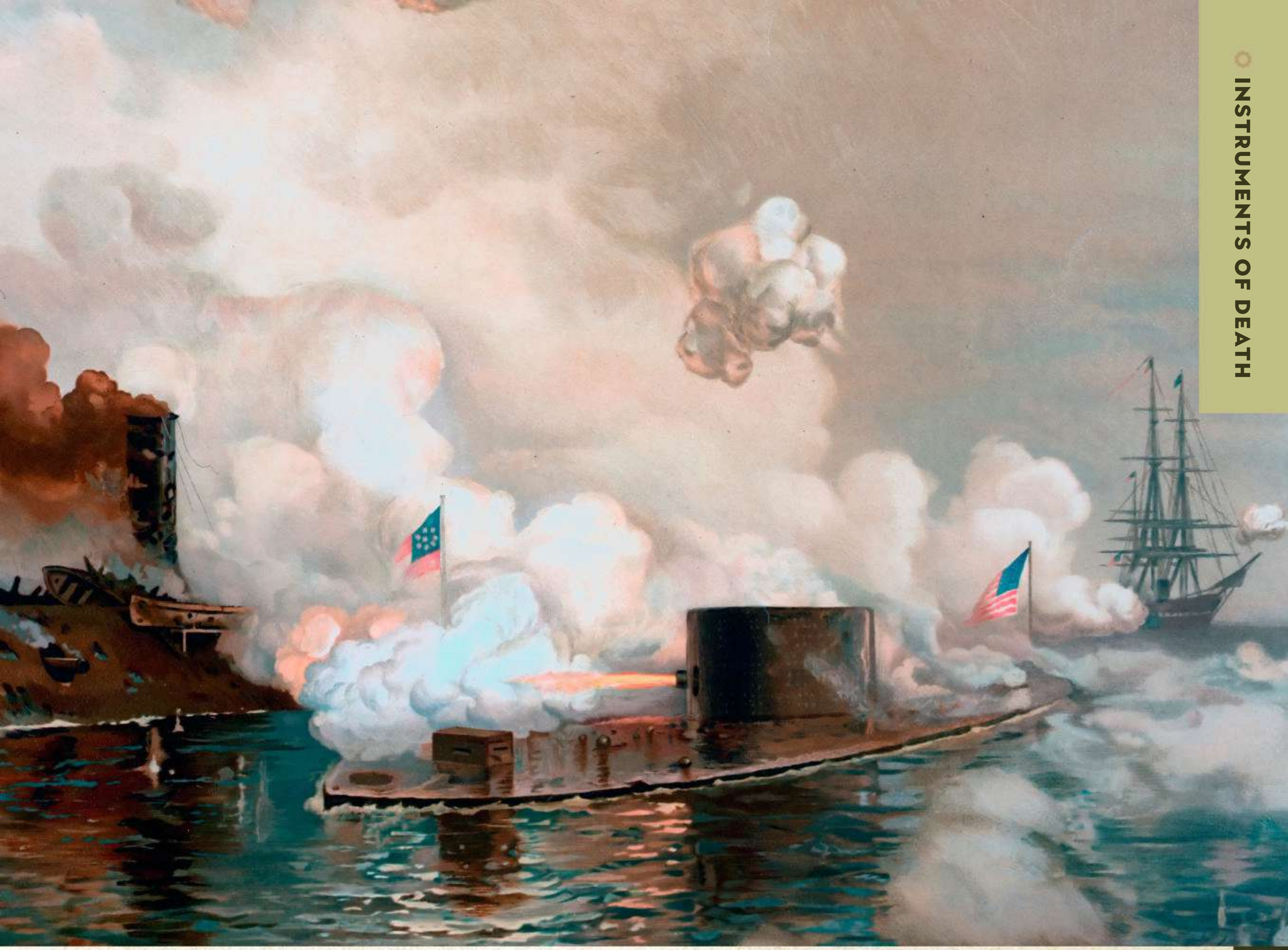
Key to the destructiveness of the American Civil War were the railways. Every major battle that took place east of the Mississippi River happened within 32 kilometres (20 miles) of a railway. The railway brought men to battle, along with supplies and ammunition, and then evacuated the injured.



▶ The Battle of Hampton Roads, the first naval fight between ironclad battleships, took place during the American Civil War, in 1862



▼ On 8 August 2000, a team of archaeologists raised CSS *Hunley* from the sea bed. It was taken to the Warren Lasch Conservation Center in Charleston, where it can be seen on display



"TOTAL WAR WAS THE LOGICAL DEVELOPMENT OF INDUSTRIAL WARFARE... THE STATE, PEOPLE AND PRODUCTION WERE TURNED TOWARDS WAR"

During Sherman's March to the Sea, the devastating campaign that broke the back of the Confederate State, Sherman specifically targeted the Confederate railway system, ordering his men to heat the railway tracks until they softened and then bend them around tree trunks. The resulting loops were known as Sherman's neckties and they ensured that the Confederates could not relay their railway system after the Union army had passed.

Forced by the exigencies of war to innovate, both sides in the Civil War developed new, ironclad warships, and on 9 March 1862, they met for the first time. The CSS *Virginia* and the USS *Monitor* hurled shells at each other for four hours at the confluence of the Elizabeth, Nansemond and James rivers. Neither ship was able to inflict significant damage on the other - they were too well armoured - but the encounter brought an end to the era of wooden men of war. Henceforward, all the naval powers switched to building iron warships.

The American Civil War also saw the first use of a submarine to attack enemy shipping. Blockaded by the Union navy, the Confederacy built the CSS *Hunley*, the first true submarine, although one driven by men hand cranking the propellor. On 17 February 1864, the *Hunley* attacked the USS *Housatonic*, embedding its spar torpedo into the side of the vessel. The charge exploded and the *Housatonic* sank quickly - although the *Hunley* and its crew sank too. The age of submarine warfare had begun.

The second half of the 19th century produced further wars that accelerated the adoption of new technologies of war, even while military doctrines remained largely bound by the now outmoded tactics of the Napoleonic era. Only the German general staff truly embraced the new way of war, studying the application of the technologies of the modern world to the battlefield. Their efforts would come to terrible fruition in the Great War.

▲ The destruction and defence of railways and rolling stock were essential parts of the Union strategy during the American Civil War

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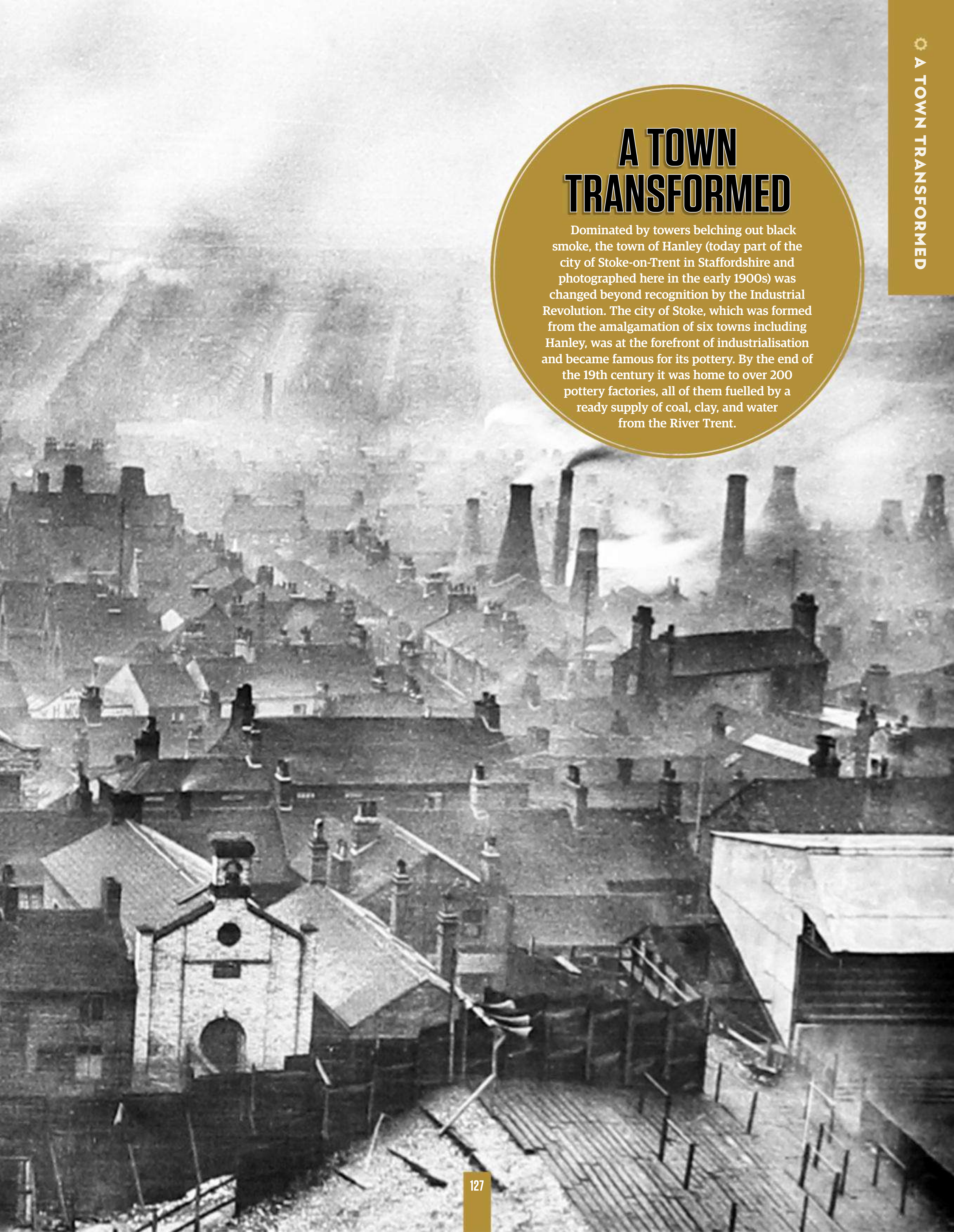
A TOWN TRANSFORMED

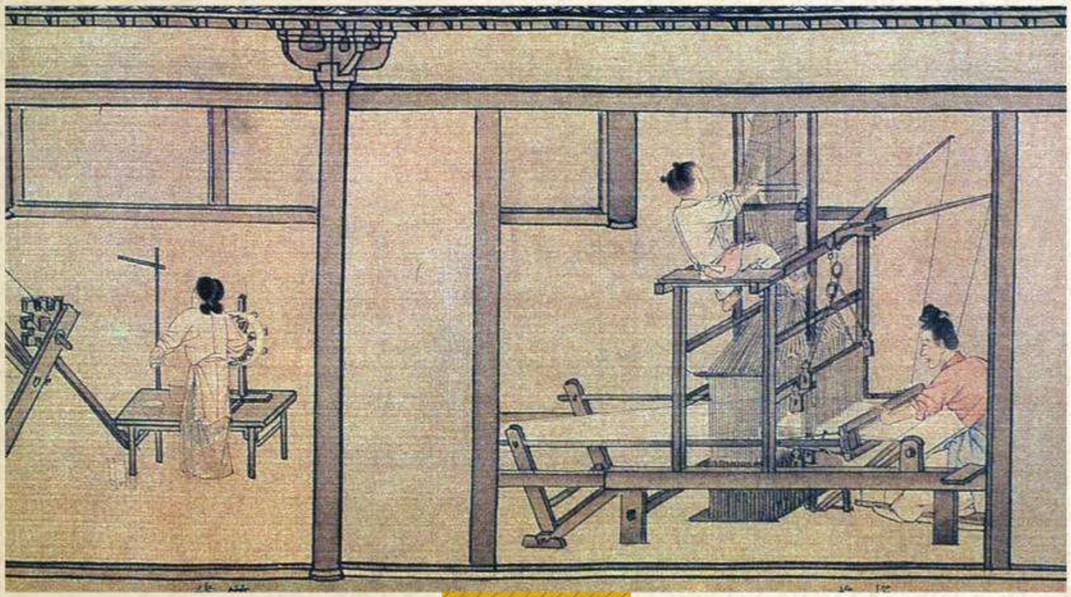


Dominated by towers belching out black smoke, the town of Hanley (today part of the city of Stoke-on-Trent in Staffordshire and photographed here in the early 1900s) was changed beyond recognition by the Industrial Revolution. The city of Stoke, which was formed from the amalgamation of six towns including Hanley, was at the forefront of industrialisation and became famous for its pottery. By the end of the 19th century it was home to over 200 pottery factories, all of them fuelled by a ready supply of coal, clay, and water from the River Trent.

WHAT IF THE INDUSTRIAL REVOLUTION HAD HAPPENED DURING THE SONG DYNASTY?

Technological developments changed the face of 18th-century Britain, but what if 12th-century China had got there first?

Written by Callum McKelvie



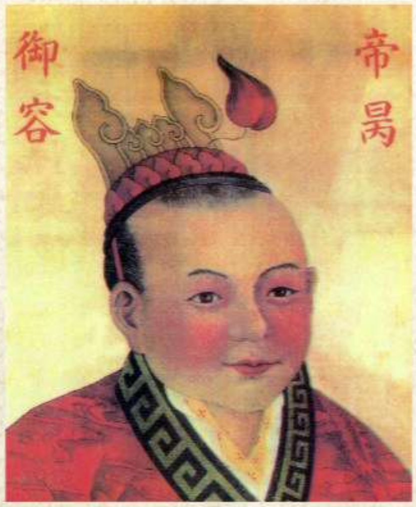
China's abundance of silk worms helped fuel the silk industry during the Song dynasty

In mid-18th century Britain, something extraordinary began to happen. New sources of power, such as coal, were harnessed and essential materials, including iron, became much cheaper and of better quality. Groundbreaking inventions, perhaps most importantly the steam engine, led to countries developing a reliance on machine production. This period, known as the Industrial Revolution, fundamentally altered the course of history and is a flashpoint, not only for Britain, but the entire world. However, centuries earlier, on the other side of the globe, another country came very close to experiencing an industrial revolution of its own. What the consequences of this would have been we can only wonder…

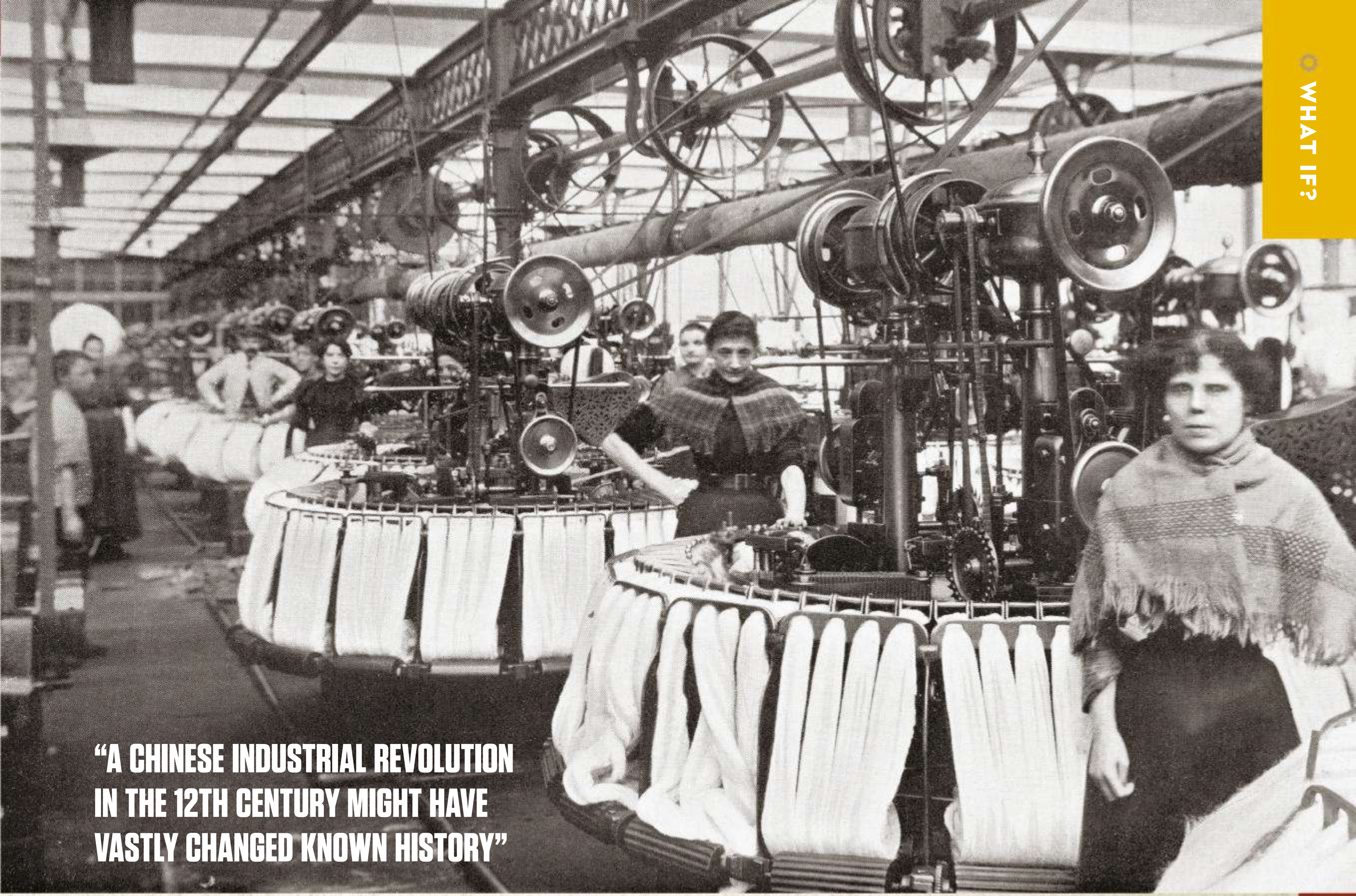
But before we journey backwards and sideways in time, we must explore what led to the Industrial Revolution in Britain in 1750. "What was so special about Britain?" economic historian Joel Mokyr ponders. "Historians have differing opinions on this," he explains. "One factor is geography. Britain is an island which, since the end of the Civil War in 1649, had avoided any organised violence on its soil, nor had it been successfully invaded. Being an island, internal transportation was easier – nowhere is more than 110 kilometres (68 miles) from the coast. Of course it has the necessary materials, such as coal and iron, but these are just some of a number of reasons."

Yet surely these are not factors that were unique to Britain in the 1750s? Is there not perhaps another time and place where political stability coupled with technological advancements could have combined to create the necessary environment in which an industrial revolution may have occurred? "The only period historians believe was on the verge of an industrial revolution is China during the Song dynasty," Mokyr suggests.

The Song dynasty ruled from 960–1279 CE and is considered a period of great technological achievement that saw the windmill introduced to China and also the invention of gunpowder. This stability was largely thanks to the Emperor Taizu, who ended the division of the



The last ruler of the Song dynasty, Emperor Zhao Bing's death ended any hope of an industrial revolution in China



“A CHINESE INDUSTRIAL REVOLUTION IN THE 12TH CENTURY MIGHT HAVE VASTLY CHANGED KNOWN HISTORY”

Ten Kingdoms and unified China once more. Author Robert B. Marks states in *China: Its Environment and History* that the Song industrial revolution featured “revolutions in farming” as well as “in water transport, in money and credit, in markets and urbanisation and in science and technology”.

“They begin to make heavy use of cotton, harness coal and iron and utilise sophisticated machinery – it looks like the kind of economy that could have become an industrial revolution,” Mokyr continues.

Of course much of the machinery utilised by the Song dynasty was different from that which would be invented centuries later – namely it was powered by wind and water – but is it possible it could have developed into something far more advanced? “They still could have achieved a lot,” Mokyr muses. “Who knows? They might even have eventually invented the steam engine.”

So what would a world with an industrial revolution that had begun in 12th-century China have looked like?

“China might at that time have become the technological and economical dominant power in the world,” Mokyr speculates. “It’s quite possible that we would all be speaking Chinese.”

A Chinese industrial revolution in the 12th century might have vastly changed known history. What if they had managed to invent the steam engine, as Mokyr earlier speculated? Would steam power trains and possibly even ships have followed soon after? Perhaps even a global empire, the likes of which the world had never seen?

Mokyr remains sceptical of this idea. “It’s more likely that the Chinese would have stayed within the confines of China, unlike the Europeans, who sailed around the world imposing their power and beliefs on other nations.”

Whatever the possibilities, it was not to be. In 1211, the Mongol Empire had begun to steadily invade China. By 1279, they had all but taken the great nation when the seven-year-old emperor, Zhao Bing, drowned during the Battle of Yamen. A brave minister plunged the pair of them into the ocean in a desperate attempt to save the boy from his attackers. His death signalled the end of the Song dynasty and Kublai Khan became the first Mongol ruler of all of China.

There are other factors to consider, though. “18th-century Europe is the age of the Enlightenment,” Mokyr explains. “There is a wide belief in progress that society can be made better. On the other hand, the Song dynasty represents the triumph of what’s known as Neo-Confucianism. This is essentially a set of values in which the highest priority of society is stability, peace and loyalty to one’s family and people. There is no serious concept of progress.

“Perhaps Chinese culture would have become the dominant culture – just as Western culture became the dominant culture in our world. But that would have required a major rewrite of global history. Frankly, the likelihood that it could have happened isn’t particularly high.”

▲ (Top) The Industrial Revolution saw manufacturing turn to a reliance on machinery

▲ A Victorian-era steam engine pump. Could this have been invented in 12th-century China?

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INDUSTRIAL REVOLUTION

Future PLC Quay House, The Ambury, Bath, BA1 1UA

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GPSR EU RP (for authorities only)
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hello@eucompliancepartner.com, +3375690241

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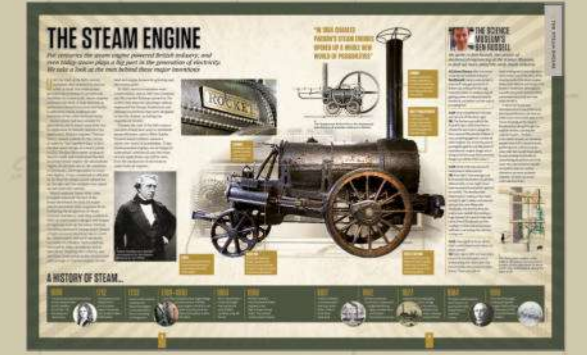

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